AVIATION SAFETY RESEARCH

HEARING

BEFORE THE

SUBCOMMITTEE ON
INVESTIGATIONS AND OVERSIGHT

AND THE

SUBCOMMITTEE ON TRANSPORTATION,
AVIATION AND MATERIALS

OF THE

COMMITTEE ON
SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

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[*] On assignment to Budget Committee for 97th Congress.

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AVIATION SAFETY RESEARCH

TUESDAY, MARCH 9, 1982

HOUSE OF REPRESENTATIVES, COMMITTEE ON SCIENCE AND TECHNOLOGY, SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT AND SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS,

Washington, D.C.

The subcommittees met, pursuant to notice, at 9:10 a.m., room 2141, Rayburn House Office Building, Hon. Albert A. Gore, Jr. [chairman] presiding.

Present: Representatives Gore, Glickman, Shamansky, Walker, Hollenbeck, and Dunn.

Mr. GORE. The hearing will come to order.

Good morning to all. Unfortunately, the task of congressional oversight is not always pleasant or easy, and conducting a hearing initiated by our recent air tragedies certainly falls into the unpleasant category.

Despite the impressive overall positive trends in aviation in the past decade, this country is still plagued by periodic avoidable disasters in our airline system. In 1979, the Subcommittee on Investigations and Oversight convened to examine the tragic crash of an American Airlines DC-10 at Chicago's O'Hare International Airport. This led the subcommittee to make some recommendations about the design of large jets. Now, some time later, we are forced to convene again, in conjunction with our sister subcommittee, as a result of new disasters.

These accidents serve as unfortunate, but forceful catalysts for the Congress to review the Federal Government's role in air safety. Sadly, there is always an element of "too little, too late" to after-the-fact proceedings like this. By the same token, it is difficult to imagine a more propitious time to be reviewing our progress in the field of air safety.

It is not our task today to find the last word and final judgment about the cause of Air Florida Flight 90, or the incident soon after at Logan Airport. That analysis is the job of the National Transportation Safety Board, and as we all know, they have been conducting their own hearings and investigation to accomplish that end.

However, we are interested in what possible factors contributed to those accidents, particularly when it points to a deficiency in our air safety program. Simple logic seems to dictate that we can learn from our mistakes.

Moreover, in that this is a committee charged with overseeing the Federal Government's scientific and technological undertakings, we are particularly interested in how research, development, and technology can contribute to preventing occurrences like last January 13.

For instance, it appears that we are very close to having the technology and data necessary to give pilots the precise information they need about traction on a runway. It does not require much imagination to see the usefulness of such a device, certainly at Logan Airport in the middle of an ice storm.

Not all our safety research needs are new stories. There has been a lot of attention and Federal research directed at the interiors of commercial aircraft, and how we might make them safer in the event of a crash. Our job today will be to examine the progress of some ongoing aviation safety programs and see if they are achieving their goals in a timely manner.

Mr. Glickman and I would also like to thank all the witnesses in advance for their time and energy in participating in this proceeding. Hopefully, our combined, cooperative effort will help the country reach its goal of a safer air transportation system.

Cochairing this hearing is Dan Glickman, and I would like to recognize him at this time.

Mr. GLICKMAN. Thank you, Al.

I think Congress clearly has a responsibility to assure continued oversight of issues involving aviation safety, and we certainly should push for utilization of improved technology when feasible in areas where it would help us to avoid accidents.

I don't think there is any question that our Nation's air system is the best and the safest in the world, but the recent accidents in Boston and Washington, as well as in numerous other accidents involving other types of aircraft, remind us that the impact of severe weather can be unpredictable and disastrous. We need to be sure that our Government continues to make progress in assuring that our aviation safety needs are being pursued vigorously.

Now, while a lot of issues fall under the umbrella of "aviation safety," I think there are some that come in the forefront. Issues that we will be particularly interested in today—some Al mentioned—are airport operations in bad weather, cabin interior roles, bad weather in relation to icing, and human factors.

The final thing I would mention in connection with these hearings is that there is a perception that perhaps the FAA has not been always as effective or timely in dealing with safety hazards, and its actions are often perceived to be reactive instead of anticipatory. And I would hope that during these hearings we could try to determine what is the institutional relationship between the FAA and the other agencies of Government, for example the National Transportation Safety Board, NASA and the Department of Defense, and maybe look for ways to try to improve the methods by which Government regulates air safety.

Thank you, Mr. Chairman.

Mr. GORE. I would like to recognize the ranking minority member of the Investigations and Oversight Subcommittee, Congressman Bob Walker.

Mr. WALKER. Thank you very much, Mr. Chairman.

Mr. Chairman, our hearing today is one that I feel we must approach with some care. We are meeting in the wake of a great tragedy; the investigation of the Air Florida accident is still ongoing. I'm not a pilot nor am I an aeronautical engineer, but I am concerned about this issue. I've been involved in numerous hearings, both in this committee and in the Government Operations Subcommittee, on the subject of air safety.

Our jurisdiction in this committee covers research and development. We will try to determine today what research is needed to make air travel even safer than it now is. The statistics show that commercial air travel is the safest form of travel. As we all know, statistics can be misleading. No other form of travel is so tightly controlled; no other form of travel is so highly regulated; no other form of travel is so closely scrutinized by the Federal Government; and no other form of travel has been the beneficiary of so much Federal research. All of this should give us a great sense of security.

As a layman I must say that after reviewing the reports concerning the crash of Palm 90, I am shocked. Each day of testimony indicates a new villain. Each day exposes another question. As I said earlier, I'm not a pilot, but it seems to me that there has been a rush to judgment in some forums. Pilot error seems to be a convenient way to lay blame, particularly when the flight crew did not survive and cannot defend themselves.

Now let me make clear, I am not saying that the crew of Palm 90 was not at fault. Clearly, they appear to have made several tragic errors and miscalculations. But what about the pressure they felt from their own operations people to make a schedule? What about their expectations that their aircraft was designed to be safe to fly in all reasonably expected environments? What about their expectations that they cannot safely rely on the operating procedures contained in their flight manual? And what about their expectations that they would be properly deiced, or that deicing equipment would operate correctly?

But, of course, there were other contributing factors, more factors than I can discuss here today, or, perhaps, than we can cover in a committee meeting here today. The point is there seems to be a great deal of blame to be apportioned here, and some of it was not in the cockpit of the airplane. Another thing which concerns me is that many have questioned the decision of the crew to launch, but there were 15 or 16 other crews who took off without incident both before and after Palm 90, and others landed during the same period without problems.

I happen to think that it is important to ask: If they were right, then why wasn't the decision of the Air Florida crew equally right? If the crew of Palm 90 was so wrong who else was equally wrong? I cannot help but ask why, why we didn't spend a few extra dollars to buy some lumber and paint and have distance-to-go markers to give the pilot visual reference at that instant when the sinking feeling in the pit of his stomach says that he might have to abort his takeoff, and the one and only thing he needs to know is "Do I have enough runway left before I put this plane into the Potomac?"

Finally, I am deeply concerned that the research in this area is woefully fragmented. There is evidence that in several areas of crash survivability, which I intend to take up in detail later today, that the FAA has been aware of serious problems, critical problems, life-threatening problems, for as long as 20 years and still has done nothing about these problems. That is unforgivable. It bespeaks indifference toward the job of protecting human life.

I can neither understand nor defend an agency process which takes 8 years considering—yes, I said considering—a rule to control toxic smoke and fumes which kill passengers who live through a survivable crash. Also, I cannot understand why, nearly 15 years after FAA's own in-house research clearly indicated that aircraft seats had collapsed in survivable accidents, thus injuring more people or even killing passengers who would have otherwise survived, we are still forced to sit in seats designed with a standard developed in the 1950's. In the years since we adopted that standard we have sent a man to the moon, we have sent a spacecraft to the outer limits of the solar system, we have developed materials with magical qualities, and yet we are reaching the 21st century with our seats firmly planted in the past.

This Nation is considered a world leader in air transport. It seems obvious that the time has long since passed when we can expect or even accept that our research efforts can run decades behind industry progress.

Thank you, Mr. Chairman.

Mr. GORE. Thank you.

Congressman Jim Dunn is serving as ranking member of the Subcommitttee on Transportation, Aviation and Materials.

Mr. DUNN. I would only make one statement, and that is that I am a pilot and I use the same runway that Palm 90 used every single weekend going in and out of National, and yet I do not feel qualified to comment on that accident or the accident at Logan, and would urge the members of the committee to keep this hearing within the realm of the things that we do have control over, and that's the general issues of safety as they pertain to runway conditions, seats, air traffic control, et cetera, and not get into the specific causes of the last two or three accidents.

Mr. GORE. Thank you very much.

Our first witness is James Burnett, Acting Chairman of the National Transportation Safety Board, accompanied by Barry Sweedler, Deputy Director for Management in the Bureau of Technology.

Welcome, gentlemen, and, Mr. Burnett, without objection, your entire prepared statement will be put into the record at this point and we invite you to present a summary or all of it as you see fit.

STATEMENT OF JIM BURNETT, ACTING CHAIRMAN, NATIONAL TRANSPORTATION BOARD; ACCOMPANIED BY BARRY SWEEDLER, DEPUTY DIRECTOR FOR MANAGEMENT, BUREAU OF TECHNOLOGY, NATIONAL TRANSPORTATION SAFETY BOARD

Mr. BURNETT. Thank you.

Chairman Gore and Chairman Glickman, this morning I would like to highlight the Safety Board's concern regarding research and development in four general areas: weather, cabin safety, crashworthiness and human performance.

Let me first turn to aviation safety research and weather considerations. Weather is a significant factor in aviation accidents involving all types of operations—air carrier, commuter and general aviation. From 1975 to 1980 weather has been cited as a cause or factor in about 40 percent of the fatal U.S. general aviation and commuter accidents, and in 52 percent of the fatal U.S. air carrier accidents; 4,000 people lost their lives as a result of these accidents.

The Safety Board has been concerned with aviation weather problems for many years and has made numerous safety recommendations regarding weather facilities, services and procedures to the Federal Aviation Administration and the National Weather Service.

Over the years, the Safety Board has made a number of recommendations dealing with improving presently available weather equipment in order to insure expeditious dissemination of timely weather information to both air traffic controllers and pilots.

The need for this research was highlighted during the investigation of the crash of a Southern Airways DC-9 at New Hope, Ga., in 1977. The investigation revealed that water on the cover or dome over the radar antenna at the nose of the aircraft may have weakened the signal and presented the pilots with a false picture of the weather they were about to encounter. The board recommended that a study be made to determine the effects of water on the radar dome. As a result of this recommendation NASA is presently engaged in a program to evaluate the effects of precipitation on radomes. In addition, NASA is also studying the effects of rain on the lift and drag characteristics of the wings and horizontal stabilizers. We believe these programs should be given high priority.

Our concern in this area was highlighted again in June of 1980 with the crash of an Air Wisconsin turbo prop aircraft in eastern Nebraska. In strikingly similar conditions to the New Hope accident, the aircraft had encountered severe thunderstorms and experienced a loss of power due to massive water ingestion. As a result of this accident the Safety Board recommended that the FAA expedite the development of an integrated radar system having the capability of displaying accurate weather echo intensity information. We understand that the FAA is currently making progress in this area and that controllers have responded positively to the concept. The FAA will continue testing over the next several years and expects implementation of a system to begin in the 1984–1985 timeframe. We believe this is a very important program having significant safety implications and that the program must be given high priority for completion.

The Board has also been concerned about some aspects of airport operations during bad weather. Winter weather brings on problems caused by contamination of runways by ice, snow, slush or standing water. These conditions, which can affect aircraft takeoff and landing performance as well as controllability, have long been of concern to the Board.

It has been long recognized that a reliable method to determine the friction coefficient of runways under dry, wet, icy or snowy conditions is essential. The use of a truck or an automobile with no special instrumentation to determine the slipperiness of a runway obviously does not bear much relationship to aircraft operations.

Pilot braking reports are also unreliable and are merely a matter of opinion, with no basis for correlation to other aircraft. A more precise and repeatable method is needed.

Based on the events of the recent weeks, and on the long history of the inadequacy of runway slipperiness measurements, an all-out effort must be made to solve this problem that is with us both summer and winter and which can affect most seriously aircraft during both takeoff and landing.

The Safety Board has also been very concerned with the area of aircraft icing, including both airframe icing and engine icing. The Board recently issued 10 related recommendations based on its continuing investigation of the crash of Air Florida Flight 90 on January 13, 1982, near Washington National Airport. These recommendations addressed the problems of engine inlet pressure probe icing, faulty engine instrument readings caused by engine inlet pressure probe blockage, the use and effectiveness of deicing fluids, and extended delays during ground operations in inclement weather prior to departure. The Board recommended that the FAA advise operators of the hazards of an accumulation of snow on aircraft while on the ground after deicing, study the effectiveness of deicing techniques, and publish guidelines establishing adequate and safe deicing and anti-icing procedures.

Last year the Safety Board conducted a study and published a special report on the problems of aircraft structural icing. The study showed that the present system of forecasting icing conditions is inadequate in that it forecasts icing in general terms of intensity and does not consider the wide variation of ice accumulation characteristics of different aircraft and different deicing/anti-icing systems in use. The Safety Board subsequently made recommendations calling for the combined efforts of several agencies to develop economical instruments to measure the principal icing parameters of temperature, liquid water content and drop size in the atmosphere, develop methods to forecast these parameters, and publish the effects of variations of these parameters on individual aircraft types.

The result of this work, if accomplished, would provide icing forecasts that would be directly applicable to specific aircraft and allow the certification of an aircraft to operate in those icing conditions demonstrated to be safe for that particular aircraft.

The next area I would like to discuss is aircraft cabin safety. In 1979, and again in 1980, the Safety Board testified before the Committee on Public Works and Transportation of the House of Representatives regarding the frequent occurrence of postcrash fire in survivable air carrier accidents and on the effects such fires have on the materials surrounding the passengers in the aircraft cabin. Our concerns have not lessened in that regard. Statistics continue to show that about 20 percent of all air carrier accidents in passenger operations involve fire. About 25 to 30 percent of the occupants of these fire-involved aircraft die from all causes. About 15 to 20 percent of these fatalities die solely from the effects of fire or smoke. We were fortunate in 1980 and 1981 in that no fire deaths occurred in air carrier accidents during these years.

Thanks to the high level of interest of the Congress in this vital subject, the FAA, after nearly 20 years of dialog, has embarked on an ambitious program to study the fire problem in a systematic manner. In the meantime, however, the National Aeronautics and Space Administration has made specific progress in the area of fire protection, specifically the threat from burning cabin interior materials such as polyurethene seat cushions, carpeting, decorative wall paneling, and ceiling panels. In only 2 years of effort, the seat fire blocking concept, which consists of protecting the flammable seat cushions with thin layers of flame resistant materials, has resulted in the development and fabrication of seats in different combinations and configurations for testing. Ten seats already are flying in actual air carrier operations to test their operational characteristics such as comfort and durability. We are aware that full-scale fire tests have been performed on these seats and further tests are contemplated in the near future. Again, the Safety Board is very much encouraged by these developments and hopes that these efforts will result in adequate interim standards for cabin interior materials.

The Safety Board and its predecessor, the Bureau of Aviation Safety of the Civil Aeronautics Board, have urged the FAA to come to grips with the issue of aircraft crashworthiness in general, and the adequacy of the crashload factors in the Federal aviation regulations in particular. Time and again, the Safety Board's investigations have shown that occupants of aircraft, both in general and in air carrier accidents, could have survived if their seats had remained attached to the cabin floor.

Only recently, the Safety Board completed a special study on cabin safety in large transport aircraft which contains an overview of the Board's efforts in this area since the early 1960's, and which showed ample evidence, from accident investigations as well as from research, that human tolerance levels are significantly greater than the FAA officially maintains. The evidence includes a substantial body of work done within the FAA itself. It is the Safety Board's experience that the limiting factor in the survival of most occupants in survivable accidents is not their tolerance to crash forces, but the lethal nature of the aircraft interior and the inability of the seats to restrain the passengers.

Next I would like to briefly discuss the area of research and human factors, or as we prefer to call it, human performance factors in accident investigation.

The Board always has realized that the unpredictable link in the aviation system is man. Looking at accident statistics, it becomes quite clear that in aviation the flight crew is identified as a causal factor in about 66 percent of the fatal U.S. air carrier accidents. Factors involved include failure to follow approved procedures or directives, improper instrument flight rule operations, and factors related to optimium use of the crew resources available.

To better understand the capabilities as well as the limitations of the human being in the overall man-machine-environment system, much research must be done. The Safety Board itself, as a new initiative, has recently established a human performance speciality in its human factors division in an effort to better understand the underlying factors in behavior and decisionmaking of crew members as it pertains to accident causation. In the investigation of the Air Florida accident a human performance group was established, chaired by our specialist who possesses a doctorate in engineering psychology. This group will investigate, in a structured manner, the human factors involved in the circumstances of this accident. These involve operational factors, such as training, experience and procedures; behavior factors, including preaccident activities and observations as well as psychological problems; medical factors such as physical, pathological and physiological problems; work space factors, including crew station design, displays, vision; and, finally, environmental factors. However, this is an area in which considerable research is needed if we are to explain why humans make erroneous decisions or fail to make decisions in critical situations.

Before closing, Mr. Chairman, I want to raise another issue of special concern to the Safety Board. With respect to our study of the behavior of flight crews involved in accidents the Safety Board has a need for much more data on the flight crew's behavior in the cockpit and the effects of such behavior on the aircraft during an accident flight. To integrate the pilot's decisionmaking process into the overall accident picture not only requires accurate recall of what went on in the cockpit, but also what effect these actions had on the aircraft. We need to be able to more accurately correlate the voice recorded data with the events recorded on the flight data recorder. State of the art equipment not only will tell us what actions the pilot took, but it may be able to give us a better understanding about workload and mental overload, fatigue, and a host of other human factors, the knowledge of which are so urgently needed in the research performed by NASA today.

The expanded-parameter digital recorder, required on newly certificated aircraft, records not only the five basic flight parameters—altitude, air speed, magnetic heading, vertical acceleration, and pilot microphone keying—but also aircraft control data such as cockpit flight control positions and engine thrust which give valuable data on human performance under stressful situations.

The Safety Board has advocated research and development of small, lightweight, inexpensive voice recorders and digital flight data recorders, so that their installation and use will be widely accepted by the general aviation community. The Safety Board issued several safety recommendations in 1978, which called for the development of recorders for complex general aviation aircraft. The Safety Board considered these recommendations so important that it has reiterated them eight times since their original issue. To date, no satisfactory requirement has been established.

Mr. Chairman, the Safety Board has been criticized in the past for being too quick to identify an accident cause as pilot or crew error. To that criticism we can only respond that we are aware that the flight crew's actions almost always are influenced by a sequence of events over which they may or may not have control. Our efforts in human factors are oriented to the understanding of those events which are the underlying factors influencing human behavior. The effectiveness of this program is dependent on active support from all elements of the aviation community—the industry, the pilots and their associations, the FAA and the active researchers. With their cooperation, we can continue to move forward in reducing human failure in the aviation system.

Thank you, Mr. Chairman, this concludes my prepared remarks. I will be happy to answer any questions you or the members of the committee may have.

[The prepared statement of Mr. Burnett follows:]

Safety Information

National Transportation Safety Board
Washington, D.C. 20594

STATEMENT OF
HONORABLE JIM BURNETT, ACTING CHAIRMAN
NATIONAL TRANSPORTATION SAFETY BOARD
BEFORE THE
SUBCOMMITTEES ON
INVESTIGATIONS AND OVERSIGHT
AND
TRANSPORTATION, AVIATION AND MATERIALS
COMMITTEE ON SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES
REGARDING
AVIATION SAFETY

MARCH 9, 1982

Mr. Chairman, you have asked the Safety Board to appear here today to discuss aviation safety research and development. Before I begin I would like to introduce Mr. Barry M. Sweedler, Deputy Director for Management, Bureau of Technology, who has accompanied me today.

This morning I ~~would like~~ to highlight the Safety Board's concern regarding research and development in four general areas: weather, cabin safety, crashworthiness, and human performance.

Let me first turn to aviation safety research and weather considerations. Weather is a significant factor in aviation accidents involving all types of operations -- air carrier, commuter, and general aviation. From 1975 to 1980, weather has been cited as a cause or factor in about 40 percent of the fatal U.S. general aviation and commuter accidents, and in 52 percent of the fatal U.S. air carrier accidents. 4,000 people lost their lives as a result of these accidents.

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Over the years, the Safety Board has made a number of recommendations dealing with improving presently available weather equipment in order to insure expeditious dissemination of timely weather information to both air traffic controllers and pilots.

The need for this research was highlighted during the investigation of the crash of a Southern Airways DC-9 at New Hope, Georgia in 1977. The investigation revealed that water on the cover or dome over the radar antenna at the nose of the aircraft (radomes) may have weakened the radar signal and presented the pilots with a false picture of the weather they were about to encounter. The Board recommended that a study be made to determine the effects of water on the radar dome. As a result of this recommendation, NASA is presently engaged in a program to evaluate the effects of precipitation on radomes. In addition, NASA is also studying the effects of rain on the lift and drag characteristics of the wings and horizontal stabilizers. We believe these programs should be given high priority.

Our concern in this area was highlighted again in June of 1980 with the crash of an Air Wisconsin turbo prop aircraft in eastern Nebraska. In strikingly similar conditions to the New Hope accident, the aircraft had encountered severe thunderstorms, and experienced a loss of power due to massive water injestion. As a result of this accident, the Safety Board recommended that the FAA expedite the development of an integrated radar system having the capability of displaying accurate weather echo intensity information. We understand that the FAA is currently making progress in this area and that controllers have responded positively to the concept.

The FAA will continue testing over the next several years and expects implementation of a system to begin in the 1984 - 1985 time frame. We believe this is a very important program having significant safety implications and that the program must be given high priority for completion.

Also, as a result of our investigation of the Air Wisconsin accident, the Safety Board recommended to the FAA that color weather radar remote displays depicting thunderstorm activity be made available to the Center Weather Service Unit meteorologists at the Air Route Traffic Control Centers (ARTCC). These displays would allow the meteorologist to maintain continuous surveillance of thunderstorm activity within the ARTCC area of responsibility. We understand that the FAA is currently running final tests on the equipment, and expects deliveries to the Center Weather Service Units to be completed within one year. We urge that this program be given a high priority.

Another important weather related area is the detection of hazardous wind shear in the airport terminal area. Wind shear has been a cause or factor in several air carrier accidents with considerable loss of life. In 1968, the Safety Board recommended to the FAA that methods should be developed for measuring wind shear in the terminal area. The Safety Board is aware that a low-level wind shear alert system to measure wind shear within the airport boundary has been installed at 57 major airports. However, the Safety Board notes that this system does not measure vertical wind shear, or wind shear outside the airport boundary. The next generation Doppler Radars (NEXRAD Program) may provide a solution to this wind shear detection problem. However, the deployment of Doppler Radars system-wide may take another 10 years. We should consider the immediate use of current Doppler weather radar technology in high risk airport terminal areas.

The Board has also been concerned about some aspects of airport operations during bad weather. Winter weather brings on problems caused by contamination of runways by ice, snow, slush, or standing water. These conditions, which can affect aircraft take off and landing performance as well as controllability, have long been of concern to the Board.

It has been long recognized that a reliable method to determine the friction coefficient of runways under dry, wet, icy or snowy conditions is essential. The use of a truck or an automobile with no special instrumentation to determine the slipperiness of a runway obviously does not bear much relationship to aircraft operations. Pilot braking reports are also unreliable and are merely a matter of opinion, with no basis for correlation to other aircraft. A more precise and repeatable method is needed.

Much research and experimentation has been done in the past in an attempt to solve this problem. For instance, the "Mu" Meter and the diagonally braked vehicle (DBV) have been tested and are in use at some airports. However, the correlation of data from these sources to aircraft stopping capability is questionable. We understand that research is currently being conducted by NASA and the FAA with a Saab friction vehicle. The Saab vehicle uses tire slip ratios similar to those used in aircraft anti-skid systems. The data gathered with this vehicle reportedly have correlated favorably with the data collected by an instrumented FAA aircraft. This piece of equipment shows promise of providing real-time data for determining runway slipperiness more reliably. Such information would be of considerable value in evaluating the true operational condition of a runway, so that it can be transmitted to pilots. Further, such information would be of equal value to controllers and aircraft dispatchers.

Based on the events of the recent weeks, and on the long history of the inadequacy of runway slipperiness measurements, an all-out effort must be made to solve this problem that is with us both summer and winter and which can affect most seriously aircraft during both take off and landing.

The Safety Board has also been very concerned with the area of aircraft icing, including both airframe icing and engine icing. The Board recently issued ten related recommendations based on its continuing investigation of the crash of Air Florida Flight 90 on January 13, 1982, near Washington National Airport. These recommendations addressed the problems of engine inlet pressure probe icing, faulty engine instrument readings caused by engine inlet pressure probe blockage, the use and effectiveness of deicing fluids, and extended delays during ground operations in inclement weather prior to departure. The Board recommended that the FAA advise operators of the hazards of an accumulation of snow on aircraft while on the ground after deicing, study the effectiveness of deicing techniques, and publish guidelines establishing adequate and safe deicing and anti-icing procedures.

Last year the Safety Board conducted a study and published a special report on the problems of aircraft structural icing. The study showed that the present system of forecasting icing conditions is inadequate in that it forecasts icing in general terms of intensity and does not consider the wide variation of ice accumulation characteristics of different aircraft and different deicing/anti-icing systems in use. The Safety Board subsequently made recommendations calling for the combined efforts of several agencies to develop economical instruments to measure the principal icing parameters of temperature, liquid water content and drop size in the atmosphere, develop methods to forecast these parameters, and publish the effects of variations of these parameters on individual aircraft types.

The results of this work, if accomplished, would provide icing forecasts that would be directly applicable to specific aircraft and allow the certification of an aircraft to operate in those icing conditions demonstrated to be safe for that particular aircraft.

The next area I would like to discuss is aircraft cabin safety. In 1979, and again in 1980, the Safety Board testified before the Committee on Public Works and Transportation of the House of Representatives regarding the frequent occurrence of postcrash fire in survivable air carrier accidents and on the effects such fires have on the materials surrounding the passengers in the aircraft cabin. Our concerns have not lessened in that regard. Statistics continue to show that about 20 percent of all air carrier accidents in passenger operations involve fire. About 25 to 30 percent of the occupants of these fire-involved aircraft die from all causes. About 15 to 20 percent of these fatalities die solely from the effects of fire or smoke. We were fortunate in 1980 and 1981 in that no fire deaths occurred in air carrier accidents during these years.

Thanks to the high level of interest of the Congress in this vital subject, the FAA, after nearly 20 years of dialogue, has embarked on an ambitious program to study the fire problem in a systematic manner. In the meantime, however, the National Aeronautics and Space Administration has made specific progress in the area of fire protection, specifically the threat from burning cabin interior materials such as polyurethene seat cushions, carpeting, decorative wall panelling and ceiling panels. In only two years of effort, the seat fire blocking concept, which consists of protecting the flammable seat cushions with thin layers of flame resistant materials, has resulted in the development and fabrication of seats in different combinations and configurations for testing. Ten seats already are flying in actual air carrier operations to test their operational characteristics such as comfort and durability. We understand that full-scale tests have been performed on these seats and further tests are contemplated in the near future. Again the Safety Board is very much encouraged by these developments and hopes that these efforts will result in adequate interim standards for cabin interior materials.

The long-range fire related studies such as fire propagation and other physical and mathematical modeling, laboratory test methodologies and fire management, by FAA, NASA and industry also underway, are, in the view of the Safety Board, important aspects of a cabin fire safety program. The Safety Board realizes that the entire subject of fire dynamics and its management is extremely complex and that certain aspects of it, especailly the toxic effects of different gasses from burning materials on humans, are not very well understood. We would hope, however, that the FAA will not delay much needed rulemaking on the fire safety issue because of these limitations.

Another aspect of the fire threat in air carrier operations concerns the release and ignition of the aircraft's fuel. A promising potential solution to this threat, is the ongoing research and development of anti-misting kerosene (AMK). This concept, developed in the United Kingdom and under investigation by FAA for the last 10 years, involves the addition to jet fuel of low-concentration of shear-sensitive hydrocarbon polymers (FM-9). The additive prevents, to a large extent, the formation of highly flammable and explosive fuel mists when the fuel is released from damaged aircraft wings at high decelerative forces. Evaluation by the FAA of this fuel has been highly encouraging and it has shown that flame propagation through the fuel mist can be effectively reduced or entirely eliminated.

This program in the past has progressed at a slow pace until, at the urging of the Congress, an accelerated program was instituted in 1980 which also took into account the handling characteristics of this fuel. These characteristics involve fuel storage, quality control, engine compatibility and reliability. Only recently, an economic analysis was completed which indicated that the choice of the FM 9 additive may not be economically attractive. However, industry already has proposed alternative concepts which hold promise for the replacement of FM 9 without penalty. Unfortunately, FAA has been unable to fund research to qualify viable alternative fuel additives. The Safety Board strongly recommends that funds be made available so this vital fire safety program does not become stalled at the completion of this research project in 1984.

In addition to cabin safety, the Board has been long concerned with a related area, crashworthiness. For the last 20 years, the Safety Board and its predecessor, the Bureau of Aviation Safety of the Civil Aeronautics Board, have urged the FAA to come to grips with the issue of aircraft crashworthiness in general, and the adequacy of the crashload factors in the Federal Aviation Regulations in particular. Time and again, the Safety Board's investigations have shown that occupants of aircraft, both in general aviation and in air carrier accidents, could have survived if their seats had remained attached to the cabin floor.

Both the Safety Board and the FAA agree on the definition of a survivable accident. That definition is: crash forces experienced by the occupants should not exceed human tolerance limits; the structure surrounding the occupants must remain relatively intact to provide a livable environment through the crash sequence; and the occupants must remain restrained so that they may participate in the decelerative process. The disagreement between the Safety Board and the FAA appears to be in respect to what constitutes a relatively intact environment, as well as to what are the tolerance limits of the human body to decelerative forces. I should add that the FAA stands virtually alone in the safety research community with respect to its insistence that the human body, when restrained by only a seatbelt, cannot withstand significantly more inertial forces than those to which present passenger seats are designed.

Only recently, the Safety Board completed a special study on cabin safety in large transport aircraft which contains an overview of the Board's efforts in this area since the early 1960's, and which showed ample evidence from accident investigations as well as from research that human tolerance levels are significantly greater than the FAA officially maintains. The evidence includes a substantial body of work done within the FAA itself. It is the Safety Board's experience that the limiting factor in the survival of most occupants in survivable accidents is not their tolerance to crash forces, but the lethal nature of the aircraft interior and the inability of the seats to restrain the passenger.

The Safety Board recommended that FAA establish interim standards for the design of seats and restraint systems, as well as cabin furnishings to withstand multidirectional acceleration levels and to specify static as well as dynamic testing standards in the appropriate regulations.

The Safety Board is pleased to note that the FAA once again has instituted an ambitious program to study aircraft crashworthiness. This program, started in 1980, includes the development and validation of analytical techniques to predict aircraft and seat behavior; development of crash scenarios; integration of seat behavior with airframe behavior; conceptual seat studies; definition of human tolerance limitations, among many other long range studies. In reviewing these plans, however, we are concerned that the enormous data base that already exists on many of these projects seems to be ignored and precious funds are being expended in duplications of effort.

Another example is the development of crashworthy fuel systems for helicopters. The FAA contemplates spending over one million dollars over a five year period. However, the U.S. Army developed, substantiated, and has had in operational use since the 1970's, a crash resistant fuel system in its helicopters which has proven so successful that the Army has not lost an aviator because of a crash fire since it installed these systems. The Board would hope that the FAA, in an effort to expedite its research, would take advantage of existing technology and research. We are concerned that the major improvements in aircraft crashworthiness will not be seen in the next 10 to 15 years unless a conscious effort is made to use those existing data and techniques.

Next, I would like to briefly discuss the area of research in human factors, or as we prefer to call it, human performance factors in accident investigations.

The Board always has realized that the unpredictable link in the aviation system is man. Looking at accident statistics it becomes quite clear that in aviation the flightcrew is identified as a causal factor in about 66 percent of the fatal U.S. air carrier accidents. Factors involved include failure to follow approved procedures or directives, improper instrument flight rule operations, and factors related to optimum use of the crew resources available.

To illustrate this problem, allow me to review a few accidents in which the human performance factor was especially prominent: on June 7, 1971, an Allegheny prop jet made an approach to the New Haven, Connecticut Airport when it struck three beach cottages on the Long Island Sound shoreline. The captain disregarded advisories from his first officer that minimum descent altitudes had been reached and that they were less than 50 feet above the water. The weather at that time presented less than 1/4 mile visibility because of fog. Although the Board could not determine conclusively what motivated the captain to disregard prescribed operational procedures, the Board addressed two important factors that were involved in this accident. First, the role of command authority versus the need for flight crew assertiveness, that is, the relationship between the captain and the first officer. And second, the need to motivate crew members to choose safety over operating commitments.

On December 29, 1972, an Eastern L-1011 crashed into the Everglades 15 miles west of the Miami Airport in Florida. The crew executed a missed approach at night after observing an unsafe gear indication. They leveled the aircraft at 2,000 feet, put the aircraft on auto pilot and became involved in trying to resolve the apparent landing gear problem. Both pilots, the flight engineer and a mechanic who was on the jumpseat failed to notice that the altitude hold mode of the auto pilot apparently became disconnected and the aircraft slowly descended into the ground. Although there were other factors involved, the accident illustrated the importance of cockpit management and how simple but non-routine occurrences can distract the crew and lead to an accident.

To better understand the capabilities as well as the limitations of the human being in the overall man-machine-environment system, much research must be done. The Safety Board itself, as a new initiative, has recently established a human performance speciality in its human factors division in an effort to better understand the underlying factors in behavior and decision making of crew members as it pertains to accident causation. In the investigation of the Air Florida accident, a human performance group was established, chaired by our specialist who possesses a doctorate in engineering psychology. This group will investigate, in a structured manner, the human factors involved in the circumstances of this accident. These involve operational factors, such as training, experience, and procedures; behavior factors, including preaccident activities and observations as well as psychological problems; medical factors such as physical, pathological and physiological problems; work space factors, including crew station design, displays, vision, and finally environmental factors. However, this is an area in which considerable research is needed if we are to explain why humans make erroneous decisions or fail to make decisions in critical situations.

The Safety Board is encouraged by the important human factors research being performed by NASA at its Ames Research Center, as well as at the Langley Research Center. We have followed with interest the work being done in flight deck resource management which has as its heart the decision-making process and the effective utilization of the information and resources available to the captain. One of the most important gains made as a result of this research in the last decade is the line oriented flight training concept (loft) now being instituted by several major airlines. The Board encourages this research and urges the FAA to take full advantage of it as definitive information becomes available.

Other studies dealing with information transfer, cockpit automation fatigue and workload problems are significant research projects of NASA, many of which are funded by FAA, that bear on the human factor problems we face today. Since 1968, the Safety Board has made over 130 recommendations to the FAA and other organizations on the subject of human factors. These recommendations have stressed the following: one, the need to improve flight deck management so as to instill a sense of professionalism which, in turn, fosters crew discipline and crew coordination. Two, development of state of the art instrumentation so that decisions can be made from real-time information rather than from expectations, past experience and subjective confidence. Three, the institution of more realistic training requirements so that procedures can be rehearsed and fine-tuned and unexpected accident triggering contingencies, including full-scale emergencies, can be practiced in any desired sequences. We believe that NASA's research addresses many of these needs and the Board fully supports them.

Before closing, Mr. Chairman, I want to raise another issue of special concern to the Safety Board. With respect to our study of the behavior of flight crews involved in accidents, the Safety Board has a need for much more data on the flight crew's behavior in the cockpit and the effects of such behavior on the aircraft during an accident flight. To integrate the pilot's decision-making process into the overall accident picture not only requires accurate recall of what went on in the cockpit but also what effect these actions had on the aircraft. We need to be able to more accurately correlate the voice recorder data with the events recorded on the flight data recorder. State of the art equipment not only will tell us what actions the pilot took but it may be able to give us a better understanding about workload and mental overload, fatigue, and a host of other human factors, the knowledge of which are so urgently needed in the research performed by NASA today.

The expanded-parameter digital recorder required on newly certificated aircraft records not only the five basic flight parameters (altitude, airspeed, magnetic heading, vertical acceleration, and pilot microphone keying), but also aircraft control data such as cockpit flight control positions, engine thrust, etc., which give valuable data on human performance under stressful situations.

The Safety Board has advocated research and development of small, lightweight, inexpensive voice recorders and digital flight data recorders. so that their installation and use will be widely accepted by the general aviation community. The Safety Board issued several safety recommendations in 1978, which called for the development of recorders for complex general aviation aircraft. The Safety Board considered these recommendations so important that it has reiterated them eight times since their original issue. To date, no satisfactory requirement has been established.

Mr. Chairman, the Safety Board has been criticized in the past for being too quick to identify an accident cause as pilot or crew error. To that criticism we can only respond that we are aware that the flight crew's actions almost always are influenced by a sequence of events over which they may or may not have control. Our efforts in human factors are oriented to the understanding of those events which are the underlying factors influencing human behavior. The effectiveness of this program is dependent on active support from all elements of the aviation community -- the industry, the pilots and their associations, the FAA and the active researchers. With their cooperation, we can continue to move forward in reducing human failure in the aviation system.

Thank you, Mr. Chairman. This concludes my prepared remarks. I will be happy to answer any questions you or members of the Committee may have.

Mr. GLICKMAN. Thank you, Mr. Burnett.

I do have some questions. I think that you are one of the most important witnesses here, and I am sure all members of the committee will have questions.

I would like to first pursue the institutional relationship between you, the safety agency, a nonregulatory agency, a fact-finding agency, have with the FAA, which is the regulatory agency. In your testimony dealing with the issue of seats and cabin interiors you state, and I quote, "The FAA stands virtually alone in the safety research community with respect to its insistence that the human body when restrained by only a seat belt cannot withstand significantly more inertial forces than those to which present passenger seats are designed."

In addition, you indicate in your testimony that despite eight reiterations of recommendations to the FAA, no satifactory requirement has been introduced with respect to cockpit recorders in smaller aircraft. You also seem to imply in your statement a series of long-standing concerns about your recommendations to the FAA.

I would like to ask you a general question: Would you characterize the FAA as being uncooperative in dealing with your safety recommendations?

Mr. BURNETT. No, I would not so characterize the FAA, but I would like to point out that I think the Safety Board should not be easily satisfied. That's the institutional position that we must adopt. I think we must be responsible and reasonable, but we must be demanding with the FAA. They adopted approximately 80 percent of the recommendations that we submit to them. The FAA adopted, for instance, most of the recommendations made after the Air Florida accident. They accepted three out of four of the most urgent that we gave them.

Mr. GLICKMAN. Were these the ones concerning deicing procedures?

Mr. BURNETT. Yes, those were the deicing procedures and they also concerned the decisionmaking process in bad weather conditions. And they were very responsive to our deicing procedure recommendations, less so to those having to do with the decisionmaking process.

Mr. GLICKMAN. I forgot. What was your recommendation on the decisionmaking process?

Mr. BURNETT. We made some recommendations as far as training of controllers so that they might be better aware of the seriousness of conditions in bad weather situations, gate-hold procedures, that sort of thing; and we also recommended that the flight crews be required to make a visual inspection when there is falling frozen precipitation. The FAA did not respond favorably to that, perhaps because we included a requirement that deicing be conducted every 20 minutes under certain conditions. It is possible that the Safety Board may reconsider the 20-minute figure. As you know, we try to get out recommendations as quickly as possible because of the necessity of doing so. It wouldn't do any good to make recommendations on icing conditions next summer. And we are in the process of refining those recommendations, and we may add additional recommendations to them.

I think there is, of necessity, some institutional tension between the Safety Board and the FAA, and there must continue to be so. There are several areas in which we think they have significantly failed to be responsive, and I have identified several of those—flight data recorders, crashworthiness standards, and the cabin-fire safety standards. We don't think the FAA has moved as fast as the prevailing technology can permit us to move. I think that is very serious and can involve the loss of many lives.

Mr. **GLICKMAN**. OK, we will get into those two issues specifically in questions. I just wanted to get your basic statement on the nature of the relationship.

I am very concerned about your budget this year and in the following year. Many of your recommendations have proved more dramatic in enhancing air safety than anything done independently by any other agency, and yet I see that you are going to be left with a budget which will strain you rather dramatically.

I wonder, would another investigation on the scale of the Air Florida flight 90 crash seriously deplete your budget for this year?

Mr. **BURNETT**. We are under a great deal of budgetary strain. We do not yet know how much the cost is going to be for the Air Florida investigation, because it is still continuing. What is now clear to us is that shortly after Air Florida we had the World Airways accident in Boston, and we were not able to give it the attention that we should have been able to because of lack of manpower and resources. And had we had another accident of that type in aviation at the same time, we literally would not have been able to deal with it.

Mr. **GLICKMAN**. And if you would have had other kinds of transportation accidents, too, it would have been almost impossible for you to have given it any proper investigative oversight.

Mr. **BURNETT**. We did have other nonaviation major accidents during that time. Aviation was not the only area in which there was a rash of transportation accidents during that period, and we were overextended. There are none of our aviation experts able to be here at the table with me today simply because they are involved in Air Florida. We are stretched to the limits of our capability.

Mr. **GLICKMAN**. What did the President's budget propose for next year for your agency?

Mr. **BURNETT**. $17,600,000.

Mr. **GLICKMAN**. And what is it this year?

Mr. **BURNETT**. It is $17,125,000.

Mr. **GLICKMAN**. So it is virtually the same. You have almost the same budget as you did last year.

One final question and I will go on to Mr. Walker.

There has been some criticism that appointments to the NTSB, including yourself, do not represent the people experienced in transportation issues, whether they be aviation or whatever. I'm not sure of your background but I don't believe that you have an extensive background in aviation. This agency has been alleged to be the receptacle of political appointments for people who may have helped in Presidential campaigns, and it is not just this administration but the past one as well.

I wonder if you would comment on that and comment on whether that causes you any problems in getting the FAA, who have people experienced in aviation, to listen to you? That is, if they don't believe that you have a background in transportation but you are, so to speak, political hacks—and I say that for purposes of emphasis—why should they listen to you at all?

Mr. **Burnett**. In response to that I would say that there may be some value to having someone who is experienced in the political arena to maneuver the FAA into the position of having to do what they should do. I certainly hope that the political background that I have will serve me in good stead in that process. I recall the President's statement, when he was talking about the appointment of inspectors general, that he wanted people who are "meaner than a junk yard dog," and I think we have assumed the watchdog function, and I think it is helpful to have people who have abilities outside the technical field.

We have a very fine technical staff at the Safety Board. They are not public policy makers, and I think there is a need to have participation on the Safety Board of people who have that kind of perspective and that kind of background.

Mr. **Glickman**. I guess my point is there is some concern that if you have people who are all there because of political reasons, then you won't get that institutional acceptance by the regulators in the sense that they may not believe that you know what you are talking about.

Thank you.

Mr. Walker.

Mr. **Walker**. Thank you, Mr. Chairman.

In your testimony you were talking about the problems of aircraft structural icing, and you said that there is a study that showed that the present system of forecasting icing conditions is inadequate in that it forecasts icing in general terms of intensity but does not consider the wide variation of ice accumulation characteristics of different aircraft and so on.

Does the FAA have that study?

Mr. **Burnett**. Mr. Sweedler?

Mr. **Sweedler**. Yes, they do have that study, sir.

Mr. **Walker**. Has anything been done with regard to regulations based upon that study at this point?

Mr. **Sweedler**. They have not responded in a positive way on that study, and we are hoping to meet with them and continue discussions with them.

Mr. **Walker**. So, in other words, the testimony previously of Mr. Burnett with regard to icing relates to the emergency kinds of recommendations that you made following the Air Florida crash and has nothing to do with some of the things that have been studied in a lot more depth and where there have been specific recommendations made upon long-term study, is that correct?

Mr. **Sweedler**. The study itself dealt with airborne icing problems.

Mr. **Walker**. This study is on airborne icing problems?

Mr. **Sweedler**. Primarily with general aviation aircraft. Yes, sir.

Mr. **Walker**. Very good; thank you.

There have been some new reports on the Air Florida crash which indicated that most of the people in the crash lost their lives as a result of the seats breaking away in the crash. Has the evidence that you have accumulated to this point confirmed what we have heard in news reports?

Mr. **Burnett**. No, it has not. Having said that, I would like to caution the committee that the Safety Board has not as yet thoroughly analyzed all the facts from Air Florida. However, I would not say that I have seen any facts to support that consideration. In the full statement that I submitted to the committee we pointed out that in order to be survivable there has to be basic structural integrity of the fuselage, and it is quite clear that it was not in this case. And although there were failures of seat structures, when there is no floor for the seats to be attached to that really does not have as much relevance.

Mr. **Walker**. Well, that is understandable, and we certainly don't want to be in a position in this hearing of asking you to comment on things where you haven't arrived at decisions. The reason why I asked in the way I did was that I think the news reports at this point have led some people to draw some conclusions about the crash that may not hold up when the studies are complete. I want to get into the question of the seating in airplanes.

The testimony that you gave indicated that you don't believe the FAA has been responsive to NTSB recommendations in the area of seating. Am I correct that the present seating standard goes back to the 1950's?

Mr. **Burnett**. Yes, it does. And there is a suggestion here that there has been no technological advancement since the 1950's. We think there has been, but the FAA has just failed to take advantage of it.

Mr. **Walker**. So, in other words, we are presently using seating standards which relate to propeller driven aircraft rather than to the far more sophisticated kind of aircraft that we have flying the airways today?

Mr. **Burnett**. I don't think that I would want to relate our seating standards to the sophistication of the aircraft. One of the great savings in lives that might be achieved would be to increase the seating standards for general aviation aircraft, so that we are not just talking about increasing those standards for jet aircraft but also for the full range of aircraft. But, yes, I think what the Congressman is driving at is that we have had great progress in the technology of the plane, but none in the technology of the cabin.

Mr. **Walker**. Am I correct that the seats that are in most commercial airplanes flying today are less rigid in terms of their structure than the seats that are in automobiles?

Mr. **Burnett**. That's correct.

Mr. **Walker**. You point out in your testimony that the FAA has taken up a study of crashworthiness and is investigating the seating standards. You also indicate, however, that a data base which has been previously developed in order to get at principally the things the FAA claims to be looking at is not being used. Are you charging that we have the FAA out reinventing the wheel in order, I take it, to delay the implemention of the standards that you have set—or suggested, I should say?

Mr. **Burnett**. I believe my predecessor, Chairman King, perhaps used that in testimony and I would not retreat from that position. We think that they have done a great deal of research. Much of it is their own through the excellent work of the Civil Aeromedical Institute in Oklahoma City. And we think that they are just not using what they already have. Certainly we haven't achieved the final solution yet, but do we have to wait for eternity in order to begin the process of improving?

Mr. **Walker**. Your testimony indicated that the reason that they have given you relates to what they regard as medical evidence that the human torso is not able to survive belted into a seat that would stay rigid.

Mr. **Burnett**. I understand that that's their position, although I don't think their own research supports that position.

Mr. **Sweedler**. That's correct.

Mr. **Walker**. So, in other words, you would question their own research on that.

Are they giving you any other reasons? Or is it a reason of economics or anything like that that may have entered into their decision?

Mr. **Burnett**. Well, I think that we would all understand that probably there may be some economic motivations. I don't know whether they have ever been expressed. The other reason that they give is that 'Well, we can do more research; we can do better; we can learn more." And, of course, while we are waiting for the research to be done lives are being lost, and the Safety Board's position is we need to do what we can now with the state of the art, and then continue the research and development and then ask for more. And we are going to continue to demand more, we are going to demand the state of the art from the FAA as we go along, but we need what we can do, let's do now.

Mr. **Walker**. One final question, Mr. Chairman.

How many lives would you estimate have been lost as a result of not having proper seat standards?

Mr. **Burnett**. I would hesitate to make an estimation of that nature. It is possible that we can submit that to you for the record, although I would want to be very cautious about developing a statistic that we might not be sound in. I don't know whether we can determine that.

Mr. **Walker**. But you are convinced that lives have been lost——

Mr. **Burnett**. Yes.

Mr. **Walker** [continuing]. Specifically for that particular reason?

Mr. **Burnett**. And the important thing is that there have been too many lost.

Mr. **Walker**. Thank you, Mr. Chairman.

Mr. **Glickman**. Thank you, Mr. Walker.

Mr. Dunn.

Mr. **Dunn**. Thank you, Mr. Chairman.

Your testimony talked about research on runway conditions. Do you have any idea how much of your $17 million budget is spent on runway conditions?

Mr. **Burnett**. No, we do not do any direct research except our research activities investigating the accident, which is important research, but we do not research runway conditions. The National

Aeronautics and Space Administration is doing that, and I think a fairly good job.

Mr. Sweedler, would you care to comment?

Mr. **Sweedler**. That is true, there has been some work done on runway conditions. The big problem is the correlation between testing vehicles and aircraft stopping performance, and that has not really been solved.

Mr. **Dunn**. I am going to follow on because I asked this question last week of Al Albrecht from the FAA. I have some reservations about the research dollars being spent on runway conditions because of the fact that runway condition is not a measurable qualitative/quantitative thing that we can actually get a handle on.

In a condition of snow with two aircraft taking off ahead of me, if their wheels are throwing up some slush and my wheels are in a different portion of the runway I am going to have a different friction basis than the two aircraft ahead of me. In a 9,000-foot runway, if we have a cloud over part of it and the temperature is 30 degrees you are going to have a different icing condition maybe 50 feet down that runway than you do 200 feet down the runway. So I have some real problems with research for any kind of equipment that can measure the total stopping or friction capabilities of a 9,000- or 7,000-foot runway.

What I am trying to say simply is that maybe we ought to take a look at how we eliminate those conditions on the runway rather than spending research dollars on how we determine what it is. And the idea I had last week for the FAA was something we use in the construction business called heat tapes. When you put heat tapes in runway you simply don't have ice or slush, and I have asked the FAA to take a look at that as an alternative proposal.

My question to you is have you taken a look at that as a proposal? Do you understand what heat tapes are in the first place?

Mr. **Burnett**. Yes, Congressman, and we will be considering that as part of our Boston World Airways investigation. This is probably an area that is going to need some research before we can determine the feasibility of it, but, again, what we are talking about here is research and development, and we feel there is a great need in the weather-related area or a great deal more progress needed.

Mr. **Dunn**. Well, what I am suggesting is rather than research and development on a vehicle that measures the conditions of runway, how about research and development that gets rid of those conditions? It is a different type of research that I am suggesting.

Mr. **Burnett**. I think that is a very positive suggesiton.

Mr. **Dunn**. I thank you.

Mr. **Glickman**. I am just going to ask you a few more questions. One relates to human factors. You state on page 16 of your prepared testimony that human factors research depends upon the support of the rest of the aviation community, and you go on to say with their cooperation we can continue to move forward in reducing human failure in the aviation system. Are you implying that some parties' cooperation has been lacking the past?

Mr. **Burnett**. No, I don't think so, Congressman, but it is quite obvious that we are going to need the support of pilots and pilot organizations. We are going to need the support of the industry and of the general public. Any time you deal with these questions of human performance which ultimately involve psychological and highly personal questions I think that we are going to have to have public support to go forward with them. It is a delicate kind of process to investigate, much more so than the engineering aspects. I think that is what we are trying to suggest.

Mr. GLICKMAN. OK.

Going back to the runway issue that Mr. Dunn raised, has the NTSB ever made recommendations to the FAA, specific recommendations, concerning runway friction?

Mr. BURNETT. Yes, we have.

Mr. Sweedler?

Mr. SWEEDLER. Yes, sir, we have made some recommendations that dealt with runway measurement, maintenance of runway surfaces to insure runway friction; we have made recommendations dealing with aircraft certification acceleration/stop criteria; and we have also made recommendations that dealt with flight simulator training on wet runways.

Mr. GLICKMAN. When were these made? Are they over a period of time?

Mr. SWEEDLER. Over a period of time going back to the early 1970's, sir.

Mr. GLICKMAN. And have any or all of them been adopted by the FAA?

Mr. SWEEDLER. Most have, some have not. I think the one that has not dealt with the operational measuring on a day-to-day basis because of the difficulty in correlation between the testing vehicle and the aircraft stopping performance.

Mr. GLICKMAN. Did you recommend that there be a procedure by which runway icing, friction, wetness be measured on a continuous basis?

Mr. SWEEDLER. When there is water on the runway, yes.

Mr. GLICKMAN. And they have not implemented that recommendation?

Mr. SWEEDLER. My understanding is that there just isn't a vehicle that can really do that. Some progress is being made with a Saab friction vehicle and some testing is going on now with NASA and with some FAA-instrumented aircraft, but that has not really gotten to a point where it could be accepted.

Mr. GLICKMAN. On the question of cockpit recorders, you state that despite eight reiterations of recommendations to the FAA, no satisfactory requirement has been introduced to require cockpit recorders in airplanes that do not otherwise have to carry them. Would you characterize the FAA as being uncooperative in this area, or why haven't they agreed to your recommendations?

Mr. BURNETT. Well, we believe they ought to adopt our recommendations. Of course, there is such a thing as legitimate difference. I'm trying to avoid getting into a name-calling posture with the FAA because I don't think that contributes to the resolution of these safety issues. We want to concentate on discussion of the safety issues, not the relative virtue of the FAA or the NTSB.

I would like to relate to the Committee that I recently went to Rhode Island on an accident that occurred there in a commuter aircraft in which both members of the flight crew were severely burned, and, although we subsequently were able to interview one of them, it appeared at one time that we might never be able to interview either one of them. And there was no flight data recorder or cockpit voice recorder on that airplane.

We have an increasing volume of our traffic relative to the total aircraft traffic in this country in commuter aviation craft, and the FAA has not been responsive to our recommendation that it is essential for our safety knowledge that we have a simplified FDR/CVR combination in these aircraft. And until we achieve that, we are going to be losing a substantial amount of valuable safety information in both these commuter craft and also the very complex general aviation aircraft that are so common in the country today.

Mr. GLICKMAN. Thank you.

One final question, the issue is birds. I'm becoming concerned that we are producing, particularly in large corporate aircraft and in commercial aircraft, twin-jet airplanes that may be particularly susceptible to bird strikes causing engine failures. If you have three engines you have greater margin of safety than if you had two engines. There are some awful big birds around airports. And I am wondering if you have made any recommendations to the FAA on the issue of bird strikes?

Mr. BURNETT. I am absolutely totally unprepared for that question.

Mr. GLICKMAN. OK.

Mr. SWEEDLER. We have over the years dealt with that problem and I think we could provide you a synopsis. We have looked at it from the engine certification standpoint and also from keeping birds away from the runway.

Mr. GLICKMAN. I will just mention that many major airports in this country are located near water. Birds are usually near water as well, and I see this as a potential problem in times to come. I think the FAA is doing some work in it, but I would urge you to be involved with it too.

Mr. BURNETT. We will respond further to the committee on that.

[Material to be provided follows:]

The Safety Board has been involved in assessing and making recommendations with respect to the bird strike problem for several years. As early as 1968, the Board modified its procedures to provide for the reporting of bird collisions with aircraft and bird ingestion by aircraft engines as causal factors in accidents and incidents. Since that time 37 accidents and incidents involving bird strikes have been reported. These occurrences resulted in fatal injuries to 14 people and serious injuries to 22 others.

Based upon evaluation of the data collected, the Board has issued 14 safety recommendations covering a broad spectrum of subjects associated with the bird strike problem. For example, we have urged the widest possible circulation of information relating to the hazard, listing of bird hazard airports in the Airman's Information Manual, concerted action by interested parties to reduce bird populations and associated hazards at certain airports, modification of aircraft engines susceptible to bird ingestion damage and a review of windscreen design to assure adequate structural strength to withstand bird strikes. The FAA has been quite responsive to our recommendations on the subject and the dearth in recent years of reported accidents and incidents involving bird strikes is encouraging. Nevertheless, the Board recognizes that the bird problem has by no means been totally eradicated, particularly at certain airports near water or bird feeding areas. Consequently, continued attention will be devoted to identifying and documenting specific needs for further corrective action.

Mr. GLICKMAN. I want to thank you for your excellent testimony today. We appreciate your being here.

Our next witness is Mr. Al Albrecht, Associate Administrator for Engineering and Development at the FAA. Al has been before us on many occasions, and accompanying Al is Dr. Edmond Koenke, Director of the Technical Center. I think Neal Blake is here with him as well.

STATEMENT OF ALBERT P. ALBRECHT, ASSOCIATE ADMINISTRATOR FOR ENGINEERING AND DEVELOPMENT, FEDERAL AVIATION ADMINISTRATION, ACCOMPANIED BY DR. EDMOND J. KOENKE, DIRECTOR, TECHNICAL CENTER, FEDERAL AVIATION ADMINISTRATION, AND MR. NEAL A. BLAKE

Mr. ALBRECHT. Mr. Chairman, members of the subcommittees, it is a pleasure to appear before you to present an overview of our aircraft and airport safety-related research and development programs.

I am Al Albrecht, FAA's Associate Administrator for Engineering and Development. I have with me at the witness table Mr. Neal Blake, my deputy, and Dr. Edmond Koenke, the Director of our Technical Center located outside of Atlantic City, N.J. Dr. Koenke will be presenting an overview of the program. Seated behind me, we have several technical experts we may call on to answer some of your questions. They are Roy Reichenbach, Gus Sarkos, Caesar Caiafa, Bill Westfield, Bruce Singer, and Dick Adams.

Mr. Glickman, since the majority of the efforts we will be describing are currently funded in the facilities engineering and development appropriation—the FED appropriation—we have not presented them to you in our regular oversight and authorization hearings. Our aircraft safety program was reviewed in considerable depth over the past several years by other committees of the Congress. It was also reviewed as a significant element of the Special Aviation Fire and Explosion Reduction Advisory Committee's activities—the SAFER Committee. In general the SAFER Committee's report indicated that we were doing the right things in the postcrash and explosion and reduction areas.

We are continuing to comply with the SAFER Committee's recommendations, and I can report that we are on schedule with our commitments.

The responsiveness of the E. & D. program to operational requirements is maintained through bimonthly reviews I conduct jointly with Walt Luffsey, the Associate Administrator for Aviation Standards, our principal customer.

Throughout Dr. Koenke's overview, he will refer to NASA, the Air Force, the U.S. Army, the British and Canadian aviation establishments and probably a few more organizations. These programs are extremely complex and demand physical, fiscal, and specialized human resources. We believe that we and the organizations we are coordinating with are maximizing the use of our resources and avoiding duplicative effort. I won't dwell on the coordination and joint programs we carry out with NASA since it is a subject of both the FAA's and NASA's regular testimony before your subcommittee, Mr. Glickman.

Dealing with aircraft safety efforts is in many ways similar to dealing with the midair collision problem. An incident can be so traumatic that it completely overshadows years of safe dependable travel. As you are aware, we have and are continuing to apply priority effort to the midair collision problem and should have the traffic alert and collision avoidance system—known as TCAS—ready for commercial implementation in 2 years. We are pursuing the aircraft and airport safety programs with the same priority and diligence. Our presentation is intended to acquaint you with those programs.

Before turning the testimony over to Dr. Koenke, I'd like to provide you with pen-and-ink updates of our first safety, cabin safety and crashworthiness program plans. I understand these have been delivered to you. The base plans are the data we provided late last year to the House and Senate Appropriation Committees in response to their request for the status of the programs. We are, as of this date, also submitting pen-and-ink updates to those committees. The updates indicate we currently are maintaining the schedules for our congressional commitments. Our ability to continue the schedules will be dependent upon availability of resources in fiscal year 1983 and beyond.

With our agreement, I'll now turn to Dr. Koenke for the overview.

Mr. GLICKMAN. Thank you.

Dr. Koenke, it is a pleasure to have you here. What is the nature of your presentation?

Dr. KOENKE. It is a combined statement with video tapes as well a viewgraphs.

Mr. GLICKMAN. OK. Proceed.

We may need lights off, I guess?

Dr. KOENKE. Yes, that would be quite helpful.

Mr. GLICKMAN. OK.

Dr. KOENKE. Mr. Chairman and members of the subcommittees, our aircraft and airport safety programs both have as a basic objective the development of improved, cost-effective techniques for enhancing aviation safety. The programs logically and systematically address the research, development, test, and evaluation of methods for improving aircraft and airport safety.

To conform to your request on topics to be covered, I will be addressing some of our efforts relating to cabin fire safety, antimisting fuels, crashworthiness, airworthiness and airports. [Viewgraph No. 1.]

I will begin with cabin fire safety, but to put this in context, this viewgraph shows that this is only one element of a comprehensive post-crash safety program which encompasses structure crashworthiness, fuel fire prevention and cabin fire safety. Our objective of the cabin fire safety program is to increase the time available for safe passenger evacuation in the case of a cabin fire started and augmented by an external fuel fire, as well as to increase the time available to control a fire or safely land an aircraft in the event of an inflight cabin fire. [Viewgraph No. 2.]

The technical approach for improving cabin fire safety is shown on this next viewgraph. All projects under this program are based on first understanding the problem, that is, "characterization of cabin fire hazards." This is accomplished by performing the most realistic large- and full-scale fire tests possible. The FAA Technical

Center has extensive facilities for conducting this type of experimentation. Once the nature of the problem is adequately characterized and understood, three approaches to improved safety are available: Management of fire, management of materials, and management of people.

The FAA cabin fire safety program is a comprehensive program with major activities under each approach. A large number of activities are performed inhouse at the FAA Technical Center while others are under contractual agreement with other Government agencies, including NASA and the National Bureau of Standards, and with private industry. [Viewgraph No. 2A.]

The cornerstone of the cabin fire safety program is the C-133 wide-body test article located in our large-scale fire test facility. [Viewgraph No. 3.]

Shown schematically in this drawing, it is practically the size of a wide-body cabin. It enables us to evaluate improved cabin materials, safety concepts and systems under the most realistic conditions possible. For example, the effects of a large external fuel fire can be studied under controlled conditions usually not attainable outdoors. More recently, the C-133 test article was modified and used to study inflight fires.

[Video demonstration.]

Over the past year, the C-133 test article was used for two purposes: To study the characteristics of post-crash cabin fires, and to demonstrate the benefit of seat cushion fire blocking layers. Both activities were recommendations of the special aviation fire explosion reduction—commonly referred to as SAFER—advisory committee.

This segment shows ignition of a furnished section of the C-133 test article by a large external fuel fire adjacent to a fuselage opening. Extensive instrumentation provides for the measurement of air temperature, smoke density and toxic gas concentration; for example, carbon monoxide, hydrogen cyanide and others, at various cabin locations. From this data we can map the survivability throughout the cabin and determine which hazard predominates. We now understand better the dangers the people will face during a cabin fire. This test shows that shortly after 2 minutes—and we are about 1 minute and 39 seconds now—a condition known as "flashover" occurs, and within a short period thereafter survival will no longer be possible.

I think it would be worthwhile to wait for the flashover point at this time.

That is the flashover point there.

Now the question is how can we make the cabin safer? One way is to use a fire blocking layer to protect the relatively flammable flexible urethane foam cushions. In this next test, the conditions are identical to the previous test except that the cushions are protected with a fire blocking layer called Vonar. Remembering that flashover occurred shortly after 2 minutes with unprotected seats, we are going to see that the use of Vonar seat cushions provides a significant improvement—survival will be possible for over 3 minutes which will give you an improvement of about 50-some-odd seconds.

I am going to continue while this is playing, and you can recognize the flashover and the time at which that occurs. [Viewgraph No. 4.]

Seat cushion fire blocking layers are a concept that FAA believes can effectively improve safety. In this viewgraph of one of the 40 to 50 preliminary tests, the performance of the Vonar protected seat at the bottom versus the unprotected seat at the top, at the identical test time, is striking. However, Vonar carries with it a weight penalty of from 3 to 4 pounds per seat which, within this age of fuel conservation, is prohibitively high. For example, over a 10-year period, a 3-pound weight penalty could result in a Boeing 747 aircraft using approximtely an additional 200,000 gallons of fuel. Therefore, we entered into an interagency agreement with NASA to develop and evaluate low-weight fire blocking layer materials. In fact, as a part of this agreement blocking layers and improved foams, including polyimide are being evaluated this week in the Douglas aircraft cabin fire simulator under a large-scale seat fire test conditions.

Working closely with the airframe manufacturers to check the performance and durability of various candidates, several materials have been identified which appear to be effective and low weight. This work will be completed this fiscal year. [Viewgraph No. 5.]

In the summer of 1980 there were a rash of hijackings in which the hijackers threatened to ignite a cabin with spilled gasoline. We conducted a series of realistic fire tests to answer a simple question: Using available onboard means, could such a fire be brought under control, and how? After a number of exploratory tests, it became clear that the onboard hand-held extinguishers offered the most effective means of fire fighting. However, which of the four common extinguishers provided the maximum protection remained to be determined. [Video demonstration.]

This video clip is part of a film prepared in fiscal year 1981 for the airlines to illustrate the extinguishment characteristics of common hand-held extinguishers when operated against the fire.

You will see a fire burning for about 10 seconds and then you will see a specific extinguisher used. The one that is going to be used first is a water extinguisher, and the narrow stream of extinguishant does not allow for rapid application over the large fire area. The fire is not extinguished and the extinguisher gets dissipated—the agent is dissipated completely.

Here is the next test. Again, we will wait for 10 seconds after ignition of the seat and we will be using a CO_2 extinguisher. And we are going to see that although the size of the fire is reduced, that again complete extinguishment cannot be effected and the entire agent gets used up out of the bottle.

The next test is with dry chemical extinguishers. Again, the fire is knocked down significantly, but before extinguishment is complete the agent is expended in this particular case. It is quite effective except that you run out of the agent before the fire goes down completely. The flame is back up there.

Now, here is the last test. Again, we wait 10 seconds, and this is the most effective extinguisher for this fire threat and it is called Halon 1211, a halogenated hydrocarbon. The fire is extinguished in several seconds; in fact, it was unnecessary to continue applying the agent.

Based on this work, the FAA issued a general notice to the airlines recommending the use of two Halon 1211 extinguishers in every airplane. Its enthusiastic acceptance and prompt implementation by the airlines was gratifying.

Subsequent tests have been performed inside the cabin test article, using a robotlike device, to demonstrate that the Halon 1211 extinguisher is safe, based on chemical analysis of cabin air samples taken during the test. These tests were initiated as the result of concern by the airlines about toxicity, and confirmed what was expected from previous analysis—that the use of this agent is safe, as well as effective, in a large transport cabin volume.

It is interesting to note that the robot that was used here was designed by an in-house co-op student from Embry-Riddle University.

That's the robot and its TV type of device, and it aims at the fire and you can take samples of the air to determine the toxicity.

I think in the interest of time, Mr. Chairman, I will just continue on. [Viewgraph No. 6.]

We have also recently completed some very successful work to improve the heat resistance of inflatable evacuation slides.

In these full-scale tests, inflated slides were exposed to a large fuel fire. In order to obtain a controlled environment not plagued by fluctuating winds, the tests had to be run during the predawn hours to assure calm winds. I would like to add that we did not use the full-scale fire test facility because it was not completed at that time. These tests were usually witnessed by industry people. From these tests—which were the most realistic that could be performed and, therefore, the most conclusive—we learned how slides fail from radiant heat and when these failures can be expected to occur.

During the course of our testing, we demonstrated that aluminized paint—because of its high reflectivity to infrared radiation from a fuel fire—improves the heat resistance of slide fabrics by at least a factor of two and sometimes much higher, depending on the radiation level. This prompted industry to develop aluminized fabrics that were optimum from other considerations besides heat resistance; for example, low weight, high strength, and packing crease resistance.

Mr. Chairman, we have brought with us a series of exhibits, including the aluminized slide material, and we invite you and the committee members to examine them at your convenience. We have got the extinguisher and some foams and fire blocking materials here. [Viewgraph No. 7.]

In order to assist industry in evaluating developmental materials for heat resistance and to develop a means of showing compliance to a regulation, if one were proposed, we developed a bench test. This relatively simple device was shown to produce data which correlated well with full-scale test results. Seven of these units were built and given to the airframe and slide manufacturers, who use them now to screen candidate slide materials for heat resistance. This device is undergoing standardization by the American Society of Testing & Materials and is part of a proposed new technical standard order for evacuation slides; that is, a TSO. Because of this work, practically all new airplanes are being built with aluminized evacuation slides, and for many inservice airplanes the original slides are being replaced by aluminized slides.

Other cabin safety projects include toxic gas analyses, burnthrough resistant windows, protective breathing devices, emergency lighting, in-flight smoke venting, and cargo compartment fire protection. Also, various activities deal with fire modeling, test method development, and full-scale testing for the purpose of developing test methods for interior cabin materials. Cabin fire test methods and materials criteria data will be completed in 1983. We are confident that these efforts will yield further improvements in fire safety over the next several years.

Next, I will discuss external fuel fires. Some aircraft crashes result in damaged fuel systems, fuel spillage, and large pool fires. [Viewgraph No. 8.]

Based on past accident data, approximately 36 percent of the fatalities in otherwise impact-survivable crashes have been caused by fire. Although we have planned efforts to decrease this statistic through more crash resistant fuel systems, past efforts have indicated that prevention of the ignition of the spilled fuel, which is usually in the form of a fine mist, will prevent the formation of a fireball attaching to the aircraft. Prevention of such a fireball represents the highest probability of breaking the chain of events that leads to large pool fires and passenger fatalities. Hence, in accordance with the SAFER Committee recommendations, major portions of our efforts are directed at the suppression of the tendency of turbine fuel to form fine mists when subjected to high velocity airstreams. [Viewgraph No. 9.]

Our program deals with fuel modification, by using polymer additives, to suppress fuel misting characteristics. Viewing the slide now being shown, in clockwise fashion from the upper left, the test sequence with 0.2 seconds between views shows the small level of fire involvement with the release of an antimisting fuel at 20 gallons per second into an airstream moving at 140 knots. [Viewgraph No. 10.]

The next slide shows the same conditions at 160 knots, which we have classified as a failure of the fuel's flammability resistance. The fuel release rate was again 20 gallons per second. Now, although this test appears dangerous, the fireball is not attached to the airfoil and it should be noted that if the same test was conducted with normal jet A kerosene the entire area encompassed by the camera view would have been engulfed in flame.

Let us take a few minutes to view the laboratory-scale and large-scale antimisting fuel tests. [Video with narrative.]

In this clip, Mr. Chairman, the left view is the June 14, 1979, crash test of the Navy SP-2H aircraft fueled with jet A. The aircraft impact airspeed was 117 knots. The right view is the December 19, 1981, crash test with antimisting kerosene fuel. The impact airspeed was 139 knots. The port wing contained 0.35 percent FM-9 additive by weight and the starboard wing contained 0.30 percent FM-9. The differences between the fire protection of the aircraft fueled with jet A and the aircraft fueled with antimisting kerosene is fairly evident and fairly dramatic. The aircraft on the left was essentially destroyed in the postcrash fire, while the aircraft on the right did not sustain significant fire damage.

I would like to move along while this is still playing.

The current program, initiated in mid-1978 and fully defined in engineering and development program plan ED 18-4, antimisting fuel, consists of: (1) determination of the feasibility of the concept of antimisting; (2) identification of aircraft, engine and airport system-oriented problems; (3) research to provide solutions to these anticipated problems and, finally, a full-scale validation of the concept via flight test of a Boeing 727 aircraft and a crash testing of a Boeing 720 aircraft. The goal is the provide a technical data base to support a decision on implementation recommendations in mid 1984.

The work has resulted in the decision that use of the antimisting concept is technically feasible. This decision, reached in late 1980, was based on the results of evaluation of the most promising additive known as FM-9. This additive, originally formulated by the Imperial Chemical Industries, Ltd., of Great Britain, was the result of about 10 years work with the Government of the United Kingdom being the main sponsor of ICI Ltd.'s efforts. In 1978, the United States and the United Kingdom entered into a memorandum of understanding with the Royal Aeronautical Establishment and the FAA as signatories, and NASA as a third party, to conduct needed research. Since that time, the American counterpart of the ICI organization, known as ICI Americas, has taken over the development of this additive. Work conducted under this memorandum of understanding has identified various technical problems and our continuing program is designed to resolve these problems.

Next I will discuss occupant survivability from the structural crashworthiness viewpoint.

Our crashworthiness program has been, and will continue to be, based upon systematic analysis of the factors which affect occupant survivability in a crash environment. It is directed toward insuring that the aircraft structure, interior and furnishings minimize occupant injuries and fatalities in impact-survivable accidents. [Viewgraph No. 11.]

In a cooperative effort with NASA we will complete in fiscal year 1982 a program which characterizes the transport aircraft crash environment and identifies those features contributing to occupant injuries and/or fatalities. Again this program is in concurrence with SAFER committee recommendations.

A basic element of this program is a review and evaluation of accident data over a 20-year period. The data is characterized with respect to airplane size, configuration, operational phase, injuries and fatalities, structural damage, and fire hazard. The range of impact parameters associated with the respective accidents have been described in detail; flightpath velocity, sink speed, airplane attitude, terrain, and so forth. The accident data is being used to develop scenarios for potentially survivable crash conditions. The crash conditions will be those in which the occupants have a reasonable chance to escape injury when properly restrained, when safe egress is provided and when impact forces can be maintained within acceptable human tolerance limits.

In general, the program points out potential areas requiring additional design consideration relative to occupant injuries and/or fatalities, and is of paramount importance in defining the sequence and understanding of the crash environment. Furthermore, the above data is fundamental to quantifying the impact forces experienced by the aircraft and occupants in a survivable crash environment.

The aircraft parameters data, just prior to impact, are inputs to analytical models which are currently being used to quantify impact forces to the cabin interior and, more specifcally, to the seat and the occupant. Quantification of these impact forces is mandatory to properly define a survivable crash envelope and to properly design seat-restraint systems.

These forces will be determined as a function of time at any location along the aircraft, for small, medium, and large transport category aircraft. This effort is scheduled for completion in the latter part of fiscal 1982 and will provide data for the cabin interior delethalization program.

You have a video tape. [Video demonstration.]

Paralleling these efforts, the Civil Aeromedical Institute, CAMI, has completed during fiscal 1982 the static and dynamic testing of transport aircraft seats, as seen on this videotape. The first sequence is a typical static test procedure as required under current regulation, with a body block representing an occupant.

Now, the next sequence is a typical dynamic test procedure which we are currently investigating as part of our seat program. The test you are viewing represents a 9G test level.

These seats were representative of those currently used throughout the commercial aviation industry. The purpose of these tests was to establish a data base of the performance levels of inservice seats, identify failure mechanisms associated with static and dynamic testing and determine the effects of floor deformation, which is a characteristic failure mode in a survivable accident which affects seat performance.

Mr. **GLICKMAN**. If I may just interrupt you, has anybody ever thought about turning the seats around like they do in the military so you don't face forward, so that you just go back into the seat?

Dr. **KOENKE**. Yes, sir, that's been thought of.

Mr. **GLICKMAN**. I know it has been thought of, I see it in almost every military airplane that I have ever been on. Has that ever been thought of in terms of requiring that as a part of commercial aircraft seating?

Dr. **KOENKE**. What that would require is a redesign of the seat which would add sigificant weight to the seat, and there would be a weight penalty that would have to be paid to turn those seats around.

Mr. **GLICKMAN**. OK. We can talk about that later.

Dr. **KOENKE**. OK.

Mr. **GLICKMAN**. It is curious that all the research being done is with forward-facing seats. Just think, if you turned the seat around the body wouldn't go that way at all.

Dr. **KOENKE**. I believe that is going to be included in the 720 crash test, but I will defer to one of my experts on that.

Concurrently a joint effort with the U.S. Army to determine limits of human tolerance to injury is being accomplished. This effort is scheduled for completion in early fiscal year 1983 and will provide the data needed to complete the efforts on the seat/restraint system and occupant interface. The data currently in our possession is mostly applicable to young, healthy individuals, totally restrained and not representative of the commercial aviation public. The tests currently being conducted will define a range of human tolerance limits applicable to varied physiological makeups and be more representative of the flying public.

A critical parameter is knowledge of human tolerance to vertical acceleration forces which is extremely limited and virtually little or no information has been developed in many years. The vertical forces experienced during a crash impact is a critical factor in trauma fatalities because of the relative stiffness of the human spinal column. This program will provide the much needed data and also provide input for validating our mathematical model, which appears on the following videotape. [Video demonstration.]

We are viewing a three-dimensional model of an aircraft seat, occupant and restraint system subjected to a longitudinal force. It closely approximates the physiological makeup of the human and the structural and geometric makeup of the seat and accurately predicts the dynamic response of the entire seat/restraint system and occupant. We consider this effort to be an invaluable part of the studies for cabin interior delethalization. This effort will be completed in the latter part of fiscal year 1982.

This technique, together with our structural analytical model, provides us with the flexibility to mathematically determine the response of major portions of the aircraft structure, including cabin interior overhead racks, galleys and items of mass, and completes the picture for the study of occupant safety.

The output from the program; definition of crash environment, CAMI seat studies, human tolerance studies, analytical modeling, fuel containment and emergency egress will be used in the total systems approach which has been suggested at previous hearings. [Viewgraph No. 12.]

In 1984, the FAA plans to conduct a full-scale crash test of a Boeing 720 aircraft. The purpose of this test will be to evaluate the performance of antimisting fuel additives as well as to validate the crashworthiness techniques which I have just discussed.

This full-scale test will involve a fully instrumented, remotely piloted aircraft crashed in a preselected mode determined from results of the crash environment program. Specifically, the crash test experiments will focus on the performance of current, modified, and new occupant seat/restraint systems.

Now I will turn to the airworthiness segment of my presentation which includes icing, aircraft tires, aircraft materials, and cockpit alert and warning devices.

Our icing program addresses possible enhancements which could improve flight safety. We rely upon and work closely with NASA and the DOD through interagency agreements to obtain relevant information in a cost effective manner. [Viewgraph No. 13.]

This is an in-flight photograph of the U.S. Army helicopter icing spray system commonly referred to as the HISS. Under interagency agreement between the FAA and the U.S. Army, we, along with NASA and other elements of DOD are making improvements in icing simulation technology. Improvements in the HISS simulation system will be completed in fiscal year 1984. The helicopter under test is the Bell Model 412. This is the first U.S.-manufactured helicopter to seek certification for flight in known icing conditions.

The atmospheric criteria being used today is the same for helicopters, transport category, and general aviation aircraft and is considered altitude independent. Therefore, an element of our program is to reexamine atmospheric icing data to confirm their applicability to each category of aircraft. We are working in close harmony with NASA, the U.S. Army and the U.S. Air Force. This effort will initially provide atmospheric data for flight into supercooled clouds and will be completed during the latter part of fiscal year 1982. Similar data related to snow conditions will be completed by late 1984. [Viewgraph No. 14.]

This photograph depicts the unique ground-based icing simulation facility commonly referred to as the Ottowa Spray Rig. This facility is owned and operated by the Canadian National Research Council. Extensive cooperative efforts exist between the United States and Canadian Government, through a memorandum of understanding. The helicopter under test is the Bell Model 412.

The Ottowa Spray Rig has been used for the past 20 years and virtually every helicopter, U.S. and foreign, has at one time been tested in this facility. [Viewgraph No. 15.]

The Sikorsky Model 76 shown has also just undergone testing using the Ottowa Spray Rig, and is now in St. Paul, Minn., undergoing further testing using the U.S. Army HISS. Industry access to the HISS is a part of interagency agreement between the FAA and Army. [Viewgraph No. 16.]

I have thus far only addressed helicopters. This photograph is the Piper Saratoga, the second single-engine, fixed-wing aircraft to seek certification for flight in known icing conditions. While our program was initially directed at helicopter icing, it was expanded to include transport and general aviation category aircraft during fiscal year 1981. [Viewgraph No. 17.]

This next photograph depicts the ground icing process. The system shown is the Trump Model D40-D. Significant progress has been made in recent years, by industry, in solving the economic and ecological problems associated with ground deicing.

In 1981, the FAA initiated an effort to study the effectiveness of ethylene glycol-based deicing fluid concentrations. The initial phases of our study include: (1) a detailed view of current ground deicing, inspection procedures, and current guidelines; and (2)——

Mr. DUNN. Dr. Koenke, may I interrupt for a minute.

Could you go back to that picture of the Piper aircraft?

Dr. KOENKE. Yes.

Mr. DUNN. That aircraft is being certified for deicing? It doesn't have any boots on it.

Dr. KOENKE. Say again?

Mr. DUNN. That aircraft there shown as being certified for deicing doesn't have any boots on it.

Dr. **Koenke**. I said it is seeking certification. It is the second single-engine, fixed-wing aircraft seeking certification.

Mr. **Dunn**. With no boots?

Dr. **Koenke**. It hasn't been given certification yet, sir.

Mr. **Dunn**. But an aircraft is really seeking certification without boots?

Dr. **Koenke**. No, there are no boots on it as I understand. It probably will when they certify it.

OK, our final report on the icing will be published later this year.

Next I will discuss some of the FAA's structural airworthiness research and development efforts.

In this area the FAA efforts are directed toward safety improvements associated with the continued airworthiness of aircraft through the development of analysis methods and tests which will assure the integrity of aircraft systems during their operational life. [Viewgraph No. 18.]

For example, we have recently improved the technology for the repair, retread, and inspection of aircraft tires. This effort, which is accomplished with industry, will culminate with the issuance of an advisory circular in the near future. [Viewgraph No. 19.]

With fuel being an expensive resource, weight reduction in aircraft has surfaced as a primary design parameter. To gain these weight reductions the use of advanced, high strength-to-weight fiber composite materials for secondary aircraft structures, and to a lesser extent for primary structures, can be expected to become common practice. Hence, we are developing an advisory textbook on advanced fiber composite materials which is scheduled for completion in October. This textbook will assist FAA engineers in the certification of aircraft or aircraft components fabricated from these advanced materials. In addition, we are developing a low-cost portable nondestructive inspection system which will insure the structural adequacy of advanced fiber composite structures during manufacture and in-field service. The completion of this system is scheduled for fiscal 1983, and it is expected that it will be used by both industry and the airlines.

Also during fiscal 1983, we will initiate a program to evaluate the impact damage sensitivity of airframe primary structures configured from Kevlar-epoxy materials. This effort is scheduled to be completed during 1984.

This final element in the airworthiness area deals with the cockpit alert and the warning systems. The need to functionally standardize and minimize the various bells, whistles, and visuals associated with cockpit warning devices is one of our ongoing programs. As an aside, there are some 200 of these bells, whistles, and visuals in the current DC-10. We will be developing guidelines for an automated aircraft monitoring system to evaluate aircraft performance and assist the fight crew to react promptly and correctly to aircraft malfunctions or failures. Human factors are a major consideration in this program. Under sponsorship of the FAA the three major airframe manufacturers, in a cooperative effort, are developing system concepts for a flight phase status monitor.

The final segment of our briefing deals with our airport program, and more specifically runway traction, snow and ice removal, and wind shear.

Our runway surface traction program primarily addresses the potential reduction in runway friction levels on water covered runways. Our program involves research and development of friction measurement techniques and improvements of runway surface conditions to enhance aircraft braking and to reduce the chances of hydroplaning and loss of directional control under wet weather conditions. [Viewgraph No. 20.]

Our program currently involves test and evaluation of various runway surface treatments, which include grooving techniques. This research is performed using the Naval Air Engineering Center's dynamic test track located at Lakehurst, N.J. [Viewgraph No. 21.]

The operation of this facility can be seen in this video film. [Video demonstration.]

The test process involves a jet test vehicle which accelerates and brakes an air carrier aircraft tire wheel assembly in a track with controlled water depth conditions. You will note the wheel changing from normal braking to a hydroplaning condition as it leaves a grooved surface and enters upon a nongrooved surface.

Let me pause a moment for that to occur.

There is the hydroplaning effect.

I might note that we have recently installed a series of test configuration grooves in our primary runway at the FAA Technical Center. This will allow for a certain degree of inservice evaluation of the effects of grooves, as a supplement to the dynamic test track procedures. [Viewgraph No. 22.]

We have demonstrated the enhancements provided by runway grooving. We have also identified the cost/performance tradeoff associated with conventional grooving techniques. An experimental percussive grooving technique has been identified and has a cost savings potential in excess of 25 percent. This technique is currently being tested.

Future plans in this area consider design, durability, and maintenance of alternate surface treatments, tire/runway interface phenomena, and the design of a system for monitoring runway conditions. [Viewgraph No. 23.]

With respect to snow and ice control we have developed airport maintenance and ground operations procedures to improve airport operating efficiency and safety. Airport advisory circulars have been issued which recommend snow and ice removal procedures based on the complexity and nature of runway operations.

Under a separate project, we have investigated the potential of a heated runway surface to preclude snow and ice buildup. Of the three systems investigated, electrical, steam, and solar heat, the solar system appears to be the most cost/beneficial and is the most efficient in the utilization of the Nation's energy resources. However, while it is technically feasible to heat a runway surface, the capital and recurring costs for such an undertaking are a deterrent to implementation at this time. Installation costs on a single runway, for example, run in the area of $10 million, and that is 1975 dollars based on a 1975 study.

Finally, in the area of wind shear phenomenon, the FAA established six tasks:

One, Wind shear characterization; two, hazard definition; three, wind shear data management; four, ground-based wind shear detection systems; five, integration of wind shear systems and data into the National Airspace System; and six, airborne wind shear development efforts.

The first three tasks: Wind shear characterization, hazard definition and wind shear management have been completed. [Viewgraph No. 24.]

One approach to ground-based wind sheet detection is a low-level wind shear alert system which is installed at 57 major airports in the United States. This system compares the wind difference between locations around the perimeter of an airport and a centerfield location, and if a vector difference of 15 knots or more is measured, an alarm is triggered in the tower which, in turn, can notify the pilots of this event. Current planning for procurement of 60 additional systems for airports is underway. [Viewgraph 25.]

Tests are also presently underway to detect and measure wind shear in the terminal area using an ASR-8 doppler radar technique to obtain wind shear and direction. Task 5, integration of wind shear systems and data into NAS, is currently an ongoing effort. [Viewgraph No. 26.]

The sixth and last task deals with our work on airborne wind shear detection and measurement systems. Accomplishments to date include flight test evaluation of aircraft ground-speed measurement systems and flight demonstration of various cockpit displays using pilot aiding concepts. As a result of these efforts, wind shear profiles for flight simulation training have been developed and provided to the airlines.

That concludes my presentation of our aircraft and airport safety programs. I would like to repeat that I have presented specific elements of these programs in response to your request. Should you desire a complete review of all elements of the programs, I will be happy to provide that briefing at your convenience. Many of these efforts I have described are conducted at the technical center—we have a lot of facilities there—and we would welcome a visit from you so you can see them performed in real time.

Thank you very much.

[The prepared statements of Mr. Albrecht and Dr. Koenke follow:]

STATEMENT OF ALBERT P. ALBRECHT, ASSOCIATE ADMINISTRATOR FOR ENGINEERING AND DEVELOPMENT, FEDERAL AVIATION ADMINISTRATION, BEFORE THE HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY, SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS AND SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT. MARCH 9, 1982

MR. CHAIRMEN, MEMBERS OF THE SUBCOMMITTEES, IT IS A PLEASURE TO APPEAR BEFORE YOU TO PRESENT AN OVERVIEW OF OUR AIRCRAFT AND AIRPORT SAFETY RELATED RESEARCH AND DEVELOPMENT PROGRAMS.

I AM AL ALBRECHT, FAA'S ASSOCIATE ADMINISTRATOR FOR ENGINEERING AND DEVELOPMENT. I HAVE WITH ME AT THE WITNESS TABLE, MR. NEAL BLAKE, MY DEPUTY, AND DR. EDMUND KOENKE, THE DIRECTOR OF OUR TECHNICAL CENTER LOCATED OUTSIDE OF ATLANTIC CITY, NEW JERSEY. DR. KOENKE WILL BE PRESENTING THE OVERVIEW OF THE PROGRAM. SEATED BEHIND ME, WE HAVE SEVERAL TECHNICAL EXPERTS WE MAY CALL ON TO ANSWER SOME OF YOUR QUESTIONS. THEY ARE GUS SARKOS, CAESAR CAIAFA, BILL WESTFIELD, AND DICK ADAMS.

MR. GLICKMAN, SINCE THE MAJORITY OF THE EFFORTS WE WILL BE DESCRIBING ARE CURRENTLY FUNDED IN THE FACILITIES ENGINEERING AND DEVELOPMENT (FE&D) APPROPRIATION, WE HAVE NOT PRESENTED THEM TO YOU IN OUR REGULAR OVERSIGHT AND AUTHORIZATION HEARINGS. OUR AIRCRAFT SAFETY PROGRAM WAS REVIEWED IN CONSIDERABLE DEPTH OVER THE PAST SEVERAL YEARS BY OTHER COMMITTEES OF THE CONGRESS. IT WAS ALSO REVIEWED AS A SIGNIFICANT ELEMENT OF THE

SPECIAL AVIATION FIRE AND EXPLOSION REDUCTION (SAFER) ADVISORY COMMITTEE'S ACTIVITIES. IN GENERAL THE SAFER COMMITTEE'S REPORT INDICATED THAT WE WERE DOING THE RIGHT THINGS IN THE POST-CRASH AND EXPLOSION REDUCTION AREAS.

WE ARE CONTINUING TO COMPLY WITH THE SAFER COMMITTEE'S RECOMMENDATIONS, AND I CAN REPORT THAT WE ARE ON SCHEDULE WITH OUR COMMITMENTS.

THE RESPONSIVENESS OF THE E&D PROGRAM TO OPERATIONAL REQUIREMENTS IS MAINTAINED THROUGH BI-MONTHLY REVIEWS I CONDUCT JOINTLY WITH WALT LUFFSEY, THE ASSOCIATE ADMINISTRATOR FOR AVIATION STANDARDS, OUR PRINCIPAL CUSTOMER.

THROUGHOUT DR. KOENKE'S OVERVIEW, HE WILL REFER TO NASA, USAF, U.S. ARMY, THE BRITISH AND CANADIAN AVIATION ESTABLISHMENTS AND PROBABLY A FEW MORE ORGANIZATIONS. THESE PROGRAMS ARE EXTREMELY COMPLEX AND DEMAND PHYSICAL, FISCAL, AND SPECIALIZED HUMAN RESOURCES. WE BELIEVE THAT WE AND THE ORGANIZATIONS WE ARE COORDINATING WITH ARE MAXIMIZING THE USE OF OUR RESOURCES AND AVOIDING DUPLICATIVE EFFORT. I WON'T DWELL ON THE COORDINATION AND JOINT PROGRAMS WE CARRY OUT WITH NASA SINCE IT IS A SUBJECT OF BOTH THE FAA'S AND NASA'S REGULAR TESTIMONY BEFORE YOUR SUBCOMMITTEE, MR. GLICKMAN.

DEALING WITH AIRCRAFT SAFETY EFFORTS IS IN MANY WAYS SIMILAR TO DEALING WITH THE MIDAIR COLLISION PROBLEM. AN INCIDENT CAN BE SO TRAUMATIC THAT IT COMPLETELY OVERSHADOWS YEARS OF SAFE DEPENDABLE TRAVEL. AS YOU ARE AWARE, WE HAVE AND ARE CONTINUING TO APPLY PRIORITY EFFORT TO THE MIDAIR COLLISION PROBLEM AND SHOULD HAVE THE TRAFFIC ALERT AND COLLISION AVOIDANCE SYSTEM (KNOWN AS TCAS) READY FOR COMMERCIAL IMPLEMENTATION IN TWO YEARS. WE ARE PURSUING THE AIRCRAFT AND AIRPORT SAFETY PROGRAMS WITH THE SAME PRIORITY AND DILIGENCE. OUR PRESENTATION IS INTENDED TO ACQUAINT YOU WITH THOSE PROGRAMS.

BEFORE TURNING THE TESTIMONY OVER TO DR. KOENKE, I'D LIKE TO PROVIDE YOU WITH PEN AND INK UPDATES OF OUR FIRE SAFETY, CABIN SAFETY, AND CRASHWORTHINESS PROGRAM PLANS. THE BASE PLANS ARE THE DATA WE PROVIDED LATE LAST YEAR TO THE HOUSE AND SENATE APPROPRIATION COMMITTEES IN RESPONSE TO THEIR REQUEST FOR THE STATUS OF THE PROGRAMS. WE ARE AS OF THIS DATE ALSO SUBMITTING PEN AND INK UPDATES TO THOSE COMMITTEES. THE UPDATES INDICATE WE CURRENTLY ARE MAINTAINING THE SCHEDULES FOR OUR CONGRESSIONAL COMMITMENTS. OUR ABILITY TO CONTINUE THE SCHEDULES WILL BE DEPENDENT UPON AVAILABILITY OF RESOURCES IN FY 1983 AND BEYOND

WITH YOUR AGREEMENT, I'LL NOW TURN TO DR. KOENKE FOR THE OVERVIEW.

STATEMENT OF DR. EDMUND KOENKE, DIRECTOR, TECHNICAL CENTER, FAA, BEFORE THE HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY, SUBCOMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS, AND SUBCOMITTEE ON INVESTIGATIONS AND OVERSIGHT. MARCH 9, 1982.

GOOD MORNING, MR. CHAIRMAN AND MEMBERS OF THE SUBCOMMITTEES.

OUR AIRCRAFT AND AIRPORT SAFETY PROGRAMS BOTH HAVE AS A BASIC OBJECTIVE, THE DEVELOPMENT OF IMPROVED, COST-EFFECTIVE TECHNIQUES FOR ENHANCING AVIATION SAFETY. THE PROGRAMS LOGICALLY AND SYSTEMATICALLY ADDRESS THE RESEARCH, DEVELOPMENT, TEST AND EVALUATION OF METHODS FOR IMPROVING AIRCRAFT AND AIRPORT SAFETY.

TO CONFORM TO YOUR REQUEST ON TOPICS TO BE COVERED, I WILL BE ADDRESSING SOME OF OUR EFFORTS RELATING TO CABIN FIRE SAFETY, ANTIMISTING FUELS, CRASHWORTHINESS, AIRWORTHINESS AND AIRPORTS.

(VIEWGRAPH #1 ON)

I WILL BEGIN WITH CABIN FIRE SAFETY, BUT TO PUT THIS IN CONTEXT, THE VIEWGRAPH SHOWS THAT THIS IS ONLY ONE ELEMENT OF A COMPREHENSIVE POST-CRASH SAFETY PROGRAM WHICH ENCOMPASSES STRUCTURE CRASHWORTHINESS, FUEL FIRE PREVENTION AND CABIN FIRE SAFETY. THE OBJECTIVE OF THE CABIN FIRE SAFETY PROGRAM IS TO INCREASE THE TIME AVAILABLE FOR SAFE PASSENGER EVACUATION IN THE CASE OF A CABIN FIRE STARTED AND AUGMENTED BY AN EXTERNAL FUEL FIRE, AS WELL AS TO INCREASE THE TIME AVAILABLE TO CONTROL A FIRE OR SAFELY LAND AN AIRCRAFT IN THE EVENT OF AN IN-FLIGHT CABIN FIRE.

(VIEWGRAPH #1 OFF VIEWGRAPH #2 ON)

THE TECHNICAL APPROACH FOR IMPROVING CABIN FIRE SAFETY IS SHOWN ON THIS NEXT VIEWGRAPH. ALL PROJECTS UNDER THIS PROGRAM ARE BASED ON FIRST UNDERSTANDING THE PROBLEM, THAT IS, "CHARACTERIZATION OF CABIN FIRE HAZARDS." THIS IS ACCOMPLISHED BY PERFORMING THE MOST REALISTIC LARGE- AND FULL-SCALE FIRE TESTS POSSIBLE. THE FAA TECHNICAL CENTER HAS EXTENSIVE FACILITIES FOR CONDUCTING THIS TYPE OF EXPERIMENTATION. ONCE THE NATURE OF THE PROBLEM IS ADEQUATELY CHARACTERIZED AND UNDERSTOOD, THREE APPROACHES TO IMPROVED SAFETY ARE AVAILABLE: MANAGEMENT OF FIRE, MANAGEMENT OF MATERIALS, AND MANAGEMENT OF PEOPLE.

THE FAA CABIN FIRE SAFETY PROGRAM IS A COMPREHENSIVE PROGRAM WITH MAJOR ACTIVITIES UNDER EACH APPROACH. A LARGE NUMBER OF ACTIVITIES ARE PERFORMED IN-HOUSE AT THE FAA TECHNICAL CENTER WHILE OTHER ACTIVITIES ARE UNDER CONTRACTUAL AGREEMENTS WITH OTHER GOVERNMENT AGENCIES, INCLUDING NASA AND THE NATIONAL BUREAU OF STANDARDS, AND WITH PRIVATE INDUSTRY.

(VIEWGRAPH #2 OFF VIEWGRAPH #2A ON)

THE CORNERSTONE OF THE CABIN FIRE SAFETY PROGRAM IS THE C-133 WIDE-BODY TEST ARTICLE LOCATED IN OUR LARGE-SCALE FIRE TEST FACILITY.

(VIEWGRAPH #2A OFF VIEWGRAPH #3 ON)

SHOWN SCHEMATICALLY IN THIS DRAWING, IT IS PRACTICALLY THE SIZE OF A WIDE-BODY CABIN. IT ENABLES US TO EVALUATE IMPROVED CABIN MATERIALS, SAFETY CONCEPTS, AND

SYSTEMS UNDER THE MOST REALISTIC CONDITIONS POSSIBLE.

(VIEWGRAPH #2 OFF, VIEWGRAPH #3 ON)

FOR EXAMPLE, THE EFFECTS OF A LARGE EXTERNAL FUEL FIRE CAN BE STUDIED UNDER CONTROLLED CONDITIONS USUALLY NOT ATTAINABLE OUTDOORS. MORE RECENTLY, THE C-133 TEST ARTICLE WAS MODIFIED AND USED TO STUDY IN-FLIGHT FIRES.

(VIEWGRAPH #3 OFF, VIDEO ON)

OVER THE PAST YEAR, THE C-133 TEST ARTICLE WAS USED FOR TWO PURPOSES: (1) TO STUDY THE CHARACTERTISTICS OF POST-CRASH CABIN FIRES, AND (2) TO DEMONSTRATE THE BENEFIT OF SEAT CUSHION FIRE BLOCKING LAYERS. BOTH ACTIVITIES WERE RECOMMENDATIONS OF THE SPECIAL AVIATION FIRE EXPLOSION REDUCTION (SAFER) ADVISORY COMMITTEE.

THIS SEGMENT SHOWS IGNITION OF A FURNISHED SECTION OF THE C-133 TEST ARTICLE BY A LARGE EXTERNAL FUEL FIRE ADJACENT TO A FUSELAGE OPENING. EXTENSIVE INSTRUMENTATION PROVIDES FOR THE MEASUREMENT OF AIR TEMPERATURE, SMOKE DENSITY, AND TOXIC GAS CONCENTRATION; FOR EXAMPLE, CARBON MONOXIDE, HYDROGEN CYANIDE, AND OTHERS, AT VARIOUS CABIN LOCATIONS. FROM THIS DATA WE CAN MAP THE SURVIVABILITY THROUGHOUT THE CABIN AND DETERMINE WHICH HAZARD PREDOMINATES. WE NOW UNDERSTAND BETTER THE DANGERS PEOPLE WILL FACE DURING A CABIN FIRE. THIS TEST SHOWS THAT SHORTLY AFTER TWO MINUTES, A CONDITION KNOWN AS "FLASHOVER" OCCURS, AND WITHIN A SHORT PERIOD THEREAFTER, SURVIVAL WILL NO LONGER BE POSSIBLE.

THE QUESTION IS HOW CAN WE MAKE THE CABIN SAFER? ONE WAY IS TO USE A FIRE BLOCKING LAYER TO PROTECT THE RELATIVELY FLAMMABLE FLEXIBLE URETHANE FOAM CUSHIONS. IN THIS TEST, THE CONDITIONS ARE IDENTICAL TO THE PREVIOUS TEST EXCEPT THAT THE CUSHIONS ARE PROTECTED WITH A FIRE BLOCKING LAYER CALLED VONAR. REMEMBERING THAT "FLASHOVER" OCCURRED SHORTLY AFTER TWO MINUTES WITH UNPROTECTED SEATS, WE NOW SEE THAT THE USE OF A VONAR SEAT CUSHION PROVIDES SIGNIFICANT IMPROVEMENT — SURVIVAL IS NOW POSSIBLE FOR OVER THREE MINUTES OR AN IMPROVEMENT OF ABOUT 50 SECONDS.

(VIDEO OFF VIEWGRAPH #4 ON)

SEAT CUSHION FIRE BLOCKING LAYERS ARE A CONCEPT FAA BELIEVES CAN EFFECTIVELY IMPROVE SAFETY. IN THIS VIEWGRAPH OF ONE OF THE 40-50 PRELIMINARY TESTS, THE PERFORMANCE OF THE VONAR PROTECTED SEAT (BOTTOM) VERSUS THE UNPROTECTED SEAT (TOP), AT THE IDENTICAL TEST TIME, IS STRIKING. HOWEVER, VONAR CARRIES WITH IT A WEIGHT PENALTY OF FROM 3 TO 4 POUNDS PER SEAT WHICH, WITHIN THIS AGE OF FUEL CONSERVATION, IS PROHIBITIVELY HIGH. FOR EXAMPLE, OVER A 10-YEAR PERIOD, A 3-POUND WEIGHT PENALTY WOULD RESULT IN A BOEING 747 AIRCRAFT USING APPROXIMATELY AN ADDITIONAL 200,000 GALLONS OF FUEL. THEREFORE, WE ENTERED INTO AN INTERAGENCY AGREEMENT WITH NASA TO DEVELOP AND EVALUATE LOW-WEIGHT FIRE BLOCKING LAYER MATERIALS.

WORKING CLOSELY WITH THE AIRFRAME MANUFACTURERS TO CHECK THE PERFORMANCE AND DURABILITY OF VARIOUS CANDIDATES, SEVERAL MATERIALS HAVE BEEN IDENTIFIED WHICH APPEAR TO BE EFFECTIVE AND LOW-WEIGHT. THIS WORK WILL BE COMPLETED THIS FISCAL YEAR.

(VIEWGRAPH #4 ON · VIEWGRAPH 5 ON)

IN THE SUMMER OF 1980 THERE WERE A RASH OF HIJACKING IN WHICH THE HIJACKERS THREATENED TO IGNITE A CABIN WITH SPILLED GASOLINE. WE CONDUCTED A SERIES OF REALISTIC FIRE TESTS TO ANSWER A SIMPLE QUESTION: "USING AVAILABLE ON-BOARD MEANS, COULD SUCH A FIRE BE BROUGHT UNDER CONTROL, AND HOW?". AFTER A NUMBER OF EXPLORATORY TESTS, IT BECAME CLEAR THAT THE ON-BOARD HAND-HELD EXTINGUISHERS OFFERED THE MOST EFFECTIVE MEANS OF FIRE-FIGHTING. HOWEVER, WHICH OF THE FOUR COMMON EXTINGUISHERS PROVIDED THE MAXIMUM PROTECTION REMAINED TO BE DETERMINED.

(VIEWGRAPH # 5 OFF · VIDEO ON)

THIS VIDEO IS PART OF A FILM PREPARED IN FY81 FOR THE AIRLINES TO ILLUSTRATE THE EXTINGUISHMENT CHARACTERISTICS OF COMMON HAND-HELD EXTINGUISHERS WHEN OPERATED AGAINST THE FIRE.

WITH THE WATER EXTINGUISHER, THE NARROW STREAM OF EXTINGUISHANT DOES NOT ALLOW FOR RAPID APPLICATION OVER THE LARGE FIRE AREA. THE FIRE IS NOT EXTINGUISHED.

WITH THE CO2 EXTINGUISHER, ALTHOUGH THE SIZE OF THE FIRE IS REDUCED, COMPLETE EXTINGUISHMENT CANNOT BE EFFECTED.

WITH THE DRY CHEMICAL EXTINGUISHER, AGAIN, THE FIRE IS KNOCKED DOWN SIGNIFICANTLY; HOWEVER, BEFORE EXTINGUISHMENT IS COMPLETE THE AGENT IS EXPENDED.

THE MOST EFFECTIVE EXTINGUISHER FOR THIS FIRE THREAT IS AN AGENT CALLED HALON 1211, A HALOGENATED HYDROCARBON. THE FIRE IS EXTINGUISHED IN SEVERAL SECONDS; IN FACT, IT WAS UNNECESSARY TO CONTINUE APPLYING THE AGENT.

(VIDEO OFF)

BASED ON THIS WORK, THE FAA ISSUED A GENERAL NOTICE TO THE AIRLINES RECOMMENDING THE USE OF TWO (2) HALON 1211 EXTINGUISHERS IN EVERY AIRPLANE. ITS ENTHUSIASTIC ACCEPTANCE AND PROMPT IMPLEMENTATION BY THE AIRLINES WAS GRATIFYING.

(VIDEO ON)

SUBSEQUENT TESTS HAVE BEEN PERFORMED INSIDE THE CABIN TEST ARTICLE, USING A ROBOT-LIKE DEVICE, TO DEMONSTRATE THAT THE HALON 1211 EXTINGUISHER IS SAFE, BASED ON CHEMICAL ANALYSIS OF CABIN AIR SAMPLES TAKEN DURING THE TEST. THESE TESTS WERE INITIATED AS THE RESULT OF CONCERN BY THE AIRLINES ABOUT TOXICITY, AND CONFIRMED WHAT WAS EXPECTED FROM PREVIOUS ANALYSIS — THAT USE OF THIS AGENT IS SAFE, AS WELL AS EFFECTIVE, IN A LARGE TRANSPORT CABIN VOLUME.

(VIDEO OFF VIEWGRAPH #6 ON)

WE ALSO RECENTLY COMPLETED SOME VERY SUCCESSFUL WORK TO IMPROVE THE HEAT RESISTANCE OF INFLATABLE EVACUATION SLIDES.

IN THESE FULL-SCALE TESTS, INFLATED SLIDES WERE EXPOSED TO A LARGE FUEL FIRE. IN ORDER TO OBTAIN A CONTROLLED ENVIRONMENT NOT PLAGUED BY FLUCTUATING WINDS, THE TESTS HAD TO BE RUN DURING THE PREDAWN HOURS TO ASSURE CALM WINDS. I WOULD LIKE TO ADD THAT WE DID NOT USE THE FULL-SCALE FIRE TEST FACILITY BECAUSE IT WAS NOT COMPLETED AT THAT TIME. THESE TESTS WERE USUALLY WITNESSED BY INDUSTRY PEOPLE. FROM THESE TESTS — WHICH WERE THE MOST REALISTIC THAT COULD BE PERFORMED AND, THEREFORE, THE MOST CONCLUSIVE — WE LEARNED HOW SLIDES FAIL FROM RADIANT HEAT AND WHEN THESE FAILURES CAN BE EXPECTED TO OCCUR.

DURING THE COURSE OF OUR TESTING, WE DEMONSTRATED THAT ALUMINIZED PAINT — BECAUSE OF ITS HIGH REFLECTIVITY TO INFRA-RED RADIATION FROM A FUEL FIRE — IMPROVES THE HEAT RESISTANCE OF SLIDE FABRICS BY AT LEAST A FACTOR OF TWO AND SOMETIMES MUCH HIGHER, DEPENDING ON THE RADIATION LEVEL. THIS PROMPTED INDUSTRY TO DEVELOP ALUMINIZED FABRICS THAT WERE OPTIMUM FROM OTHER CONSIDERATIONS BESIDES HEAT RESISTANCE; FOR EXAMPLE, LOW-WEIGHT, HIGH STRENGTH, AND PACKING CREASE RESISTANCE. WE HAVE BROUGHT WITH US A SERIES OF EXHIBITS, INCLUDING ALUMINIZED SLIDE MATERIAL. WE INVITE YOU TO EXAMINE THEM AT YOUR CONVENIENCE.

(VIEWGRAPH #6 OFF VIEWGRAPH #7 ON)

IN ORDER TO ASSIST INDUSTRY IN EVALUATING DEVELOPMENTAL MATERIALS FOR HEAT RESISTANCE AND TO DEVELOP A MEANS OF SHOWING COMPLIANCE TO A REGULATION, IF ONE WERE

PROPOSED, WE DEVELOPED A BENCH TEST. THIS RELATIVELY SIMPLE DEVICE WAS SHOWN TO PRODUCE DATA WHICH CORRELATED WELL WITH FULL-SCALE TEST RESULTS. SEVEN OF THESE UNITS WERE BUILT AND GIVEN TO THE AIRFRAME AND SLIDE MANUFACTURERS, WHO USE THEM NOW TO SCREEN CANDIDATE SLIDE MATERIALS FOR HEAT RESISTANCE. THIS DEVICE IS UNDERGOING STANDARDIZATION BY THE AMERICAN SOCIETY OF TESTING AND MATERIALS (ASTM) AND IS PART OF A PROPOSED NEW TECHNICAL STANDARD ORDER (TSO) FOR EVACUATION SLIDES. BECAUSE OF THIS WORK, PRACTICALLY ALL NEW AIRPLANES ARE BEING BUILT WITH ALUMINIZED EVACUATION SLIDES, AND FOR MANY IN-SERVICE AIRPLANES, THE ORIGINAL SLIDES ARE BEING REPLACED BY ALUMINIZED SLIDES.

(VIEWGRAPH #7 OFF)

OTHER CABIN SAFETY PROJECTS INCLUDE TOXIC GAS ANALYSES, BURN-THROUGH RESISTANT WINDOWS, PROTECTIVE BREATHING DEVICES, EMERGENCY LIGHTING, IN-FLIGHT SMOKE VENTING, AND CARGO COMPARTMENT FIRE PROTECTION. ALSO, VARIOUS ACTIVITIES DEAL WITH FIRE MODELING, TEST METHOD DEVELOPMENT, AND FULL-SCALE TESTING, FOR THE PURPOSE OF DEVELOPING TEST METHODS FOR INTERIOR CABIN MATERIALS. CABIN FIRE TEST METHODS AND MATERIALS CRITERIA DATA WILL BE COMPLETED IN 1983. WE ARE CONFIDENT THAT THESE EFFORTS WILL YIELD FURTHER IMPROVEMENTS IN FIRE SAFETY OVER THE NEXT SEVERAL YEARS.

NEXT, I WILL DISCUSS EXTERNAL FUEL FIRES. SOME AIRCRAFT CRASHES RESULT IN DAMAGED FUEL SYSTEMS, FUEL SPILLAGE, AND LARGE POOL FIRES.

(VIEWGRAPH #8 ON)

BASED ON PAST ACCIDENT DATA, APPROXIMATELY 36% OF THE FATALITIES IN OTHERWISE IMPACT SURVIVABLE CRASHES HAVE BEEN CAUSED BY FIRE. ALTHOUGH WE HAVE PLANNED EFFORTS TO DECREASE THIS STATISTIC THROUGH MORE CRASH RESISTANT FUEL SYSTEMS, PAST EFFORTS HAVE INDICATED THAT PREVENTION OF THE IGNITION OF THE SPILLED FUEL, WHICH IS USUALLY IN THE FORM OF A FINE MIST, WILL PREVENT THE FORMATION OF A FIREBALL ATTACHING TO THE AIRCRAFT. PREVENTION OF SUCH A FIREBALL REPRESENTS THE HIGHEST PROBABILITY OF BREAKING THE CHAIN OF EVENTS THAT LEADS TO LARGE POOL FIRES AND PASSENGER FATALITIES. HENCE, IN ACCORDANCE WITH THE SAFER COMMITTEE RECOMMENDATIONS MAJOR PORTIONS OF OUR EFFORTS ARE DIRECTED AT THE SUPPRESSION OF THE TENDENCY OF TURBINE FUEL TO FORM FINE MISTS WHEN SUBJECTED TO HIGH VELOCITY AIRSTREAMS.

(VIEWGRAPH #8 OFF VIEWGRAPH #9 ON)

OUR PROGRAM DEALS WITH FUEL MODIFICATION, BY USING POLYMER ADDITIVES, TO SUPPRESS FUEL MISTING CHARACTERISTICS. VIEWING THE SLIDE NOW BEING SHOWN, IN CLOCKWISE FASHION FROM THE UPPER LEFT, A TEST SEQUENCE WITH 0.2 SECONDS BETWEEN VIEWS SHOWS THE SMALL LEVEL OF FIRE INVOLVEMENT WITH THE RELEASE OF AN ANTIMISTING FUEL AT 20 GALLONS PER SECOND INTO AN AIRSTREAM MOVING AT 140 KNOTS.

(VIEWGRAPH #9 OFF VIEWGRAPH #10 ON)

THE NEXT SLIDE SHOWS THE SAME CONDITIONS AT 160 KNOTS, WHICH WE HAVE CLASSIFIED AS A FAILURE OF THE FUEL'S FLAMMABILITY RESISTANCE. THE FUEL RELEASE RATE WAS AGAIN 20 GALLONS/SECOND. NOW, ALTHOUGH THIS TEST APPEARS DANGEROUS, THE FIREBALL IS NOT ATTACHED TO THE AIRFOIL AND IT SHOULD BE NOTED THAT IF THE SAME TEST WAS CONDUCTED WITH NORMAL JET A KEROSENE, THE ENTIRE AREA ENCOMPASSED BY THE CAMERA VIEW WOULD HAVE BEEN ENGULFED IN FLAME.

LET US TAKE A FEW MINUTES TO VIEW THE LABORATORY SCALE AND LARGE-SCALE ANTIMISTING FUEL TESTS.

(VIDEO ON, WITH 3-MINUTE NARRATION ON TAPE)

(VIEWGRAPH #10 OFF)

(SPLIT -SCREEN VIDEO OF LARGE-SCALE AMK CRASH TESTS ON)

THE LEFT VIEW IS THE JUNE 14, 1979 CRASH TEST OF THE SP-2H AIRCRAFT FUELED WITH JET A. THE AIRCRAFT IMPACT AIRSPEED WAS 117 KNOTS. THE RIGHT VIEW IS THE DECEMBER 19, 1981 CRASH TEST WITH ANTIMISTING KEROSENE FUEL. THE IMPACT AIRSPEED WAS 139 KNOTS. THE PORT WING CONTAINED A 0.35% FM-9 ADDITIVE BY WEIGHT AND THE STARBOARD WING CONTAINED 0.30% FM-9. THE DIFFERENCES BETWEEN THE FIRE PROTECTION OF THE AIRCRAFT FUELED WITH JET A AND THE AIRCRAFT FUELED WITH ANTIMISTING KERSOSENE IS DRAMATICALLY EVIDENT. THE AIRCRAFT ON THE LEFT WAS ESSENTIALLY DESTROYED BY THE POST-CRASH FIRE, WHILE THE AIRCRAFT ON THE RIGHT DID NOT SUSTAIN SIGNIFICANT FIRE DAMAGE.

(VIDEO OFF)

THE CURRENT PROGRAM, INITIATED IN MID 1978 AND FULLY DEFINED IN ENGINEERING AND DEVELOPMENT PROGRAM PLAN ED 18-4, ANTIMISTING FUEL, CONSISTS OF 1) DETERMINATION OF THE FEASIBILITY OF THE CONCEPT OF ANTIMISTING, 2) IDENTIFICATION OF AIRCRAFT, ENGINE, AND AIRPORT SYSTEM-ORIENTED PROBLEMS, 3) RESEARCH TO PROVIDE SOLUTIONS TO THESE ANTICIPATED PROBLEMS AND FINALLY, 4) FULL-SCALE VALIDATION OF THE CONCEPT VIA FLIGHT AND CRASH TESTING OF A BOEING-720 AIRCRAFT. THE GOAL IS TO PROVIDE A TECHNICAL DATA BASE TO SUPPORT A DECISION ON IMPLEMENTATION RECOMMENDATIONS IN MID FY-1984.

THE WORK HAS RESULTED IN THE DECISION THAT USE OF THE ANTIMISTING CONCEPT IS TECHNICALLY FEASIBLE. THIS DECISION, REACHED IN LATE 1980, WAS BASED ON THE RESULTS OF EVALUATION OF THE MOST PROMISING ADDITIVE KNOWN AS FM-9. THIS ADDITIVE, ORIGINALLY FORMULATED BY THE IMPERIAL CHEMICAL INDUSTRIES, LTD (ICI) OF GREAT BRITAIN WAS THE RESULT OF ABOUT 10 YEARS WORK WITH THE GOVERNMENT OF THE UNITED KINGDOM BEING THE MAIN SPONSOR OF ICI LTD'S EFFORTS. IN 1978, THE

UNITED STATES AND UNITED KINGDOM HAD ENTERED A MEMORANDUM OF UNDERSTANDING WITH ROYAL AERONAUTICAL ESTABLISHMENT AND FAA AS SIGNATOREES AND NASA AS A THIRD PARTY TO CONDUCT NEEDED RESEARCH. SINCE THAT TIME, THE AMERICAN COUNTERPART OF THE ICI ORGANIZATION, ICI AMERICAS, HAS TAKEN OVER THE DEVELOPMENT OF THIS ADDITIVE.

WORK CONDUCTED UNDER THE MEMORANDUM OF UNDERSTANDING HAS IDENTIFIED VARIOUS TECHNICAL PROBLEMS. OUR CONTINUING PROGRAM IS DESIGNED TO RESOLVE THESE PROBLEMS.

NEXT I WILL DISCUSS OCCUPANT SURVIVABILITY FROM THE STRUCTURAL CRASHWORTHINESS VIEWPOINT.

OUR CRASHWORTHINESS PROGRAM HAS BEEN AND WILL CONTINUE TO BE BASED UPON SYSTEMATIC ANALYSES OF THE FACTORS WHICH AFFECT OCCUPANT SURVIVABILITY IN A CRASH ENVIRONMENT. IT IS DIRECTED TOWARD ENSURING THAT THE AIRCRAFT STRUCTURE, INTERIOR, AND FURNISHINGS MINIMIZE OCCUPANT INJURIES AND FATALITIES IN IMPACT SURVIVABLE ACCIDENTS.

(VIEWGRAPH #11 ON)

IN A COOPERATIVE EFFORT WITH NASA, WE WILL COMPLETE IN FY-82 A PROGRAM WHICH CHARACTERIZES THE TRANSPORT AIRCRAFT CRASH ENVIRONMENT AND IDENTIFIES THOSE FEATURES CONTRIBUTING TO OCCUPANT INJURIES AND OR FATALITIES. AGAIN THIS PROGRAM IS IN CONCURRENCE WITH SAFER COMMITTEE RECOMMENDATIONS.

A BASIC ELEMENT OF THIS PROGRAM IS A REVIEW AND EVALUATION OF ACCIDENT DATA OVER A 20-YEAR PERIOD. THE DATA IS CATEGORIZED WITH RESPECT TO AIRPLANE SIZE, CONFIGURATION, OPERATIONAL PHASE, INJURIES AND FATALITIES, STRUCTURAL DAMAGE AND FIRE HAZARD. THE RANGE OF IMPACT PARAMETERS ASSOCIATED WITH THE RESPECTIVE ACCIDENTS HAVE BEEN DESCRIBED IN DETAIL; FLIGHTPATH VELOCITY, SINK SPEED, AIRPLANE ATTITUDE, TERRAIN, ETC. THE ACCIDENT DATA IS BEING USED TO DEVELOP SCENARIOS FOR POTENTIALLY SURVIVABLE CRASH CONDITIONS. THE CRASH CONDITIONS WILL BE THOSE IN WHICH THE

OCCUPANTS HAVE A REASONABLE CHANCE TO ESCAPE SERIOUS INJURY WHEN PROPERLY RESTRAINED, WHEN SAFE EGRESS IS PROVIDED AND WHEN IMPACT FORCES CAN BE MAINTAINED WITHIN ACCEPTABLE HUMAN TOLERANCE LIMITS.

IN GENERAL, THE PROGRAM POINTS OUT POTENTIAL AREAS REQUIRING ADDITIONAL DESIGN CONSIDERATION RELATIVE TO OCCUPANT INJURIES AND OR FATALITIES, AND IS OF PARAMOUNT IMPORTANCE IN DEFINING THE SEQUENCE AND UNDERSTANDING OF THE CRASH ENVIRONMENT.

FURTHERMORE, THE ABOVE DATA, IS FUNDAMENTAL TO QUANTIFYING THE IMPACT FORCES EXPERIENCED BY THE AIRCRAFT AND OCCUPANTS IN A SURVIVABLE CRASH ENVIRONMENT.

THE AIRCRAFT PARAMETERS DATA, JUST PRIOR TO IMPACT, ARE INPUTS TO ANALYTICAL MODELS WHICH ARE CURRENTLY BEING USED TO QUANTIFY IMPACT FORCES TO THE CABIN INTERIOR AND MORE SPECIFICALLY, TO THE SEAT AND OCCUPANT. QUANTIFICATION OF THESE IMPACT FORCES IS MANDATORY TO PROPERLY DEFINE A SURVIVABLE CRASH ENVELOPE AND TO PROPERLY DESIGN SEAT/RESTRAINT SYSTEMS.

THESE FORCES WILL BE DETERMINED AS A FUNCTION OF TIME AT ANY LOCATION ALONG THE AIRCRAFT, FOR SMALL, MEDIUM, AND LARGE TRANSPORT CATEGORY AIRCRAFT. THIS EFFORT IS SCHEDULED FOR COMPLETION IN THE LATTER PART OF FY82 AND WILL PROVIDE DATA FOR THE CABIN INTERIOR DELETHALIZATION PROGRAM.

(VIEWGRAPH #11 OFF) (VIDEO TAPE ON)

PARALLELING THESE EFFORTS, THE CIVIL AEROMEDICAL INSTITUTE (CAMI) HAS COMPLETED DURING FY82 THE STATIC AND DYNAMIC TESTING OF TRANSPORT AIRCRAFT SEATS, AS SEEN ON THIS VIDEOTAPE. THE FIRST SEQUENCE IS A TYPICAL STATIC TEST PROCEDURE AS REQUIRED

UNDER CURRENT REGULATION, WITH A BODY BLOCK REPRESENTING AN OCCUPANT. THE NEXT SEQUENCE IS A TYPICAL DYNAMIC TEST PROCEDURE WHICH WE ARE CURRENTLY INVESTIGATING AS PART OF OUR SEAT PROGRAM. THE TEST YOU ARE VIEWING REPRESENTS A 9G TEST LEVEL.

THESE SEATS WERE REPRESENTATIVE OF THOSE CURRENTLY IN USE THROUGHOUT THE COMMERCIAL AVIATION INDUSTRY. THE PURPOSE OF THESE TESTS WAS TO ESTABLISH A DATA BASE OF THE PERFORMANCE LEVELS OF IN-SERVICE SEATS, IDENTIFY FAILURE MECHANISMS ASSOCIATED WITH STATIC AND DYNAMIC TESTING AND DETERMINE THE EFFECTS OF FLOOR DEFORMATION, WHICH IS A CHARACTERISTIC FAILURE MODE IN A SURVIVABLE ACCIDENT WHICH EFFECTS SEAT PERFORMANCE.

(VIDEO TAPE OFF)

CONCURRENTLY, A JOINT EFFORT WITH THE U.S. ARMY TO DETERMINE LIMITS OF HUMAN TOLERANCE TO INJURY IS BEING ACCOMPLISHED. THIS EFFORT IS SCHEDULED FOR COMPLETION IN EARLY FY83 AND WILL PROVIDE THE DATA NEEDED TO COMPLETE THE EFFORTS ON THE SEAT/RESTRAINT SYSTEM AND OCCUPANT INTERFACE. THE DATA CURRENTLY IN OUR POSSESSION IS MOSTLY APPLICABLE TO YOUNG, HEATHLY, INDIVIDUALS, TOTALLY RESTRAINED AND NOT REPRESENTATIVE OF THE COMMERCIAL AVIATION PUBLIC. THE TESTS CURRENTLY BEING CONDUCTED WILL DEFINE A RANGE OF HUMAN TOLERANCE LIMITS APPLICABLE TO VARIED PHYSIOLOGICAL MAKEUP AND BE MORE REPRESENTATIVE OF THE FLYING PUBLIC.

A CRITICAL PARAMETER IS KNOWLEDGE OF HUMAN TOLERANCE TO VERTICAL ACCELERATION FORCES WHICH IS EXTREMELY LIMITED AND VIRTUALLY LITTLE OR NO INFORMATION HAS BEEN DEVELOPED IN MANY YEARS. THE VERTICAL FORCES EXPERIENCED DURING A CRASH IMPACT IS A CRITICAL

FACTOR IN TRAUMA FATALITIES BECAUSE OF THE RELATIVE STIFFNESS OF THE HUMAN SPINAL COLUMN. THIS PROGRAM WILL PROVIDE THE MUCH NEEDED DATA AND ALSO PROVIDE INPUT FOR VALIDATING OUR MATHEMATICAL MODEL, WHICH APPEARS ON THE FOLLOWING VIDEOTAPE.

(VIDEO TAPE ON)

WE ARE VIEWING A THREE-DIMENSIONAL MODEL OF AN AIRCRAFT SEAT, OCCUPANT AND RESTRAINT SYSTEM, SUBJECTED TO A LONGITUDINAL FORCE. IT CLOSELY APPROXIMATES THE PHYSIOLOGICAL MAKEUP OF THE HUMAN, AND THE STRUCTURAL AND GEOMETRICAL MAKEUP OF THE SEAT, AND ACCURATELY PREDICTS THE DYNAMIC REPSONSE OF THE ENTIRE SEAT/RESTRAINT SYSTEM AND OCCUPANT. WE CONSIDER THIS TO BE AN INVALUABLE PART OF THE STUDIES FOR CABIN INTERIOR DELETHALIZATION. THIS EFFORT WILL BE COMPLETED IN THE LATTER PART OF FY82.

(VIDEO TAPE OFF)

THIS TECHNIQUE,TOGETHER WITH OUR STRUCTURAL ANALYTICAL MODEL PROVIDES US WITH THE FLEXIBILITY TO MATHEMATICALLY DETERMINE THE RESPONSE OF MAJOR PORTIONS OFTHE AIRCRAFT STRUCTURE, INCLUDING CABIN INTERIOR OVERHEAD RACKS, GALLEYS AND ITEMS OF MASS, AND COMPLETES THE PICTURE FOR THE STUDY OF OCCUPANT SAFETY.

THE OUTPUT FROM THE PROGRAMS; DEFINITION OF CRASH ENVIRONMENT, CAMI SEAT STUDIES, HUMAN TOLERANCE STUDIES, ANALYTICAL MODELING, FUEL CONTAINMENT AND EMERGENCY EGRESS WILL BE USED IN THE TOTAL SYSTEMS APPROACH WHICH HAS BEEN SUGGESTED AT PREVIOUS HEARINGS.

(VIEWGRAPH #12 ON)

IN 1984, THE FAA PLANS TO CONDUCT A FULL-SCALE CRASH TEST OF A BOEING 720 AIRCRAFT. THE PURPOSE OF THIS TEST WILL BE TO EVALUATE THE PERFORMANCE OF ANTIMISTING FUEL ADDITIVE AS WELL AS TO VALIDATE THE CRASHWORTHINESS TECHNIQUES WHICH I HAVE JUST DISCUSSED.

THIS FULL-SCALE TEST WILL INVOLVE A FULLY INSTRUMENTED, REMOTELY PILOTED AIRCRAFT CRASHED IN A PRE-SELECTED MODE DETERMINED FROM RESULTS OF THE CRASH ENVIRONMENT PROGRAM. SPECIFICALLY, THE CRASH TEST EXPERIMENTS WILL FOCUS ON THE PERFORMANCE OF CURRENT, MODIFIED, AND NEW OCCUPANT SEAT/RESTRAINT SYSTEMS.

NOW I WILL TURN TO THE AIRWORTHINESS SEGMENT OF MY PRESENTATION WHICH INCLUDES ICING, AIRCRAFT TIRES, AIRCRAFT MATERIALS AND COCKPIT ALERT AND WARNING DEVICES.

OUR ICING PROGRAM ADDRESSES POSSIBLE ENHANCEMENTS WHICH COULD IMPROVE FLIGHT SAFETY. WE RELY UPON AND WORK CLOSELY WITH NASA AND DOD THROUGH INTERAGENCY AGREEMENTS TO OBTAIN RELEVANT INFORMATION IN A COST EFFECTIVE MANNER.

(VIEWGRAPH #12 OFF VIEWGRAPH #13 ON)

THIS IS AN IN-FLIGHT PHOTOGRAPH OF THE U.S. ARMY HELICOPTER ICING SPRAY SYSTEM COMMONLY REFERRED TO AS THE HISS. UNDER INTERAGENCY AGREEMENT BETWEEN THE FAA AND THE U.S. ARMY, WE, ALONG WITH NASA AND OTHER ELEMENTS IN DOD ARE MAKING IMPROVEMENTS IN ICING SIMULATION TECHNOLOGY. IMPROVEMENTS IN THE HISS SIMULATION SYSTEM WILL BE COMPLETED IN FY84. THE HELICOPTER UNDER TEST IS THE BELL MODEL 214. THIS IS THE FIRST U.S. MANUFACTURED HELICOPTER TO SEEK CERTIFICATION FOR FLIGHT IN KNOWN ICING CONDITIONS.

THE ATMOSPHERIC CRITERIA BEING USED TODAY IS THE SAME FOR HELICOPTERS, TRANSPORT CATEGORY, AND GENERAL AVIATION AIRCRAFT AND IS CONSIDERED ALTITUDE INDEPENDENT. THEREFORE, AN ELEMENT OF OUR PROGRAM IS TO REEXAMINE ATMOSPHERIC ICING DATA TO CONFIRM THEIR APPLICABILITY TO EACH CATEGORY OF AIRCRAFT. WE ARE WORKING IN CLOSE HARMONY WITH NASA, THE U.S. ARMY AND THE U.S. AIR FORCE. THIS EFFORT WILL INITIALLY PROVIDE ATMOSPHERIC DATA FOR FLIGHT INTO SUPERCOOLED CLOUDS AND WILL BE COMPLETED DURING THE LATTER PART OF FY82. SIMILAR DATA RELATED TO SNOW CONDITIONS WILL BE COMPLETED BY LATE FY84.

(VIEWGRAPH #13 OFF VIEWGRAPH #14 ON)

THIS PHOTOGRAPH DEPICTS THE UNIQUE GROUND-BASED ICING SIMULATION FACILITY COMMONLY REFERRED TO AS THE "OTTAWA SPRAY RIG." THIS FACILITY IS OWNED AND OPERATED BY THE CANADIAN NATIONAL RESEARCH COUNCIL. EXTENSIVE COOPERATIVE EFFORTS EXIST BETWEEN THE UNITED STATES AND CANADIAN GOVERNMENTS THROUGH A MEMORANDUM OF UNDERSTANDING. THE HELICOPTER UNDER TEST IS THE BELL MODEL 412.

THE "OTTAWA SPRAY RIG" HAS BEEN USED FOR THE PAST TWENTY YEARS AND VIRTUALLY EVERY HELICOPTER, U.S. AND FOREIGN, HAS AT ONE TIME BEEN TESTED IN THIS FACILITY.

(VIEWGRAPH #14 OFF VIEWGRAPH #15 ON)

THE SIKORSKY MODEL 76 SHOWN HAS ALSO JUST UNDERGONE TESTING USING THE OTTAWA SPRAY RIG, AND IS NOW IN ST. PAUL, MINNESOTA, UNDERGOING FURTHER TESTING USING THE U.S. ARMY HISS. INDUSTRY ACCESS TO THE HISS IS A PART OF INTERAGENCY AGREEMENT BEWTEEN THE FAA AND ARMY.

(VIEWGRAPH #15 OFF VIEWGRAPH #16 ON)

I HAVE THUS FAR ONLY ADDRESSED HELICOPTERS. THIS PHOTOGRAPH IS THE PIPER SARATOGA, THE SECOND SINGLE-ENGINE, FIXED-WING AIRCRAFT TO SEEK CERTIFICATION FOR FLIGHT IN KNOWN ICING CONDITIONS. WHILE OUR PROGRAM WAS INITIALLY DIRECTED AT HELICOPTER ICING, IT WAS EXPANDED TO INCLUDE TRANSPORT AND GENERAL AVIATION CATEGORY AIRCRAFT ICING DURING FY81.

(VIEWGRAPH #16 OFF VIEWGRAPH #17 ON)

THIS PHOTOGRAPH DEPICTS THE GROUND DEICING PROCESS. THE SYSTEM SHOWN IS THE TRUMP MODEL D40-D. SIGNIFICANT PROGRESS HAS BEEN MADE IN RECENT YEARS, BY INDUSTRY, IN SOLVING THE ECONOMIC AND ECOLOGICAL PROBLEMS ASSOCIATED WITH GROUND DEICING.

(VIEWGRAPH #17 OFF)

IN 1981, THE FAA INITIATED AN EFFORT TO STUDY THE EFFECTIVENESS OF ETHYLENE GLYCOL-BASED DEICING FLUID CONCENTRATIONS. THE INITIAL PHASES OF OUR STUDY INCLUDE: (1) A DETAILED REVIEW OF CURRENT GROUND DEICING, INSPECTION PROCEDURES, AND CURRENT GUIDELINES: AND (2) A REVIEW OF RECENT STUDIES OF THE EFFECT OF ICE AND FROST FORMATION ON AIRCRAFT PERFORMANCE. THIS PROGRAM FORMS THE BASIS FOR INFORMATION WHICH MAY IDENTIFY ADDITIONAL RESEARCH AND DEVELOPMENT REQUIRED TO ASSURE FLIGHT SAFETY. OUR FINAL REPORT WILL BE PUBLISHED LATER THIS YEAR.

NEXT, I WILL DISCUSS SOME OF THE FAA'S STRUCTURAL AIRWORTHINESS RESEARCH AND DEVELOPMENT EFFORTS.

IN THIS AREA, THE FAA'S EFFORTS ARE DIRECTED TOWARD SAFETY IMPROVEMENTS ASSOCIATED WITH THE CONTINUED AIRWORTHINESS OF AIRCRAFT THROUGH THE DEVELOPMENT OF ANALYSIS METHODS AND TESTS WHICH WILL ASSURE THE INTEGRITY OF AIRCRAFT SYSTEMS DURING THEIR OPERATIONAL LIFE.

(VIEWGRAPH #18 ON)

FOR EXAMPLE, WE HAVE RECENTLY IMPROVED THE TECHNOLOGY FOR THE REPAIR, RETREAD, AND INSPECTION OF AIRCRAFT TIRES. THIS EFFORT, WHICH WAS ACCOMPLISHED WITH INDUSTRY, WILL CULMINATE WITH THE ISSUANCE OF AN ADVISORY CIRCULAR IN THE NEAR FUTURE.

(VIEWGRAPH #18 OFF   VIEWGRAPH #19 ON)

WITH FUEL BEING AN EXPENSIVE RESOURCE, WEIGHT REDUCTION IN AIRCRAFT HAS SURFACED AS PRIMARY DESIGN PARAMETER. TO GAIN THESE WEIGHT REDUCTIONS THE USE OF ADVANCED, HIGH STRENGTH-TO-WEIGHT FIBER COMPOSITE MATERIALS FOR SECONDARY AIRCRAFT STRUCTURES, AND TO A LESSER EXTENT FOR PRIMARY STRUCTURES, CAN BE EXPECTED TO BECOME COMMON PRACTICE. HENCE WE ARE DEVELOPING AN ADVISORY TEXTBOOK ON ADVANCED FIBER COMPOSITE MATERIALS WHICH IS SCHEDULED FOR COMPLETION IN OCTOBER 1982. THIS TEXTBOOK WILL ASSIST FAA ENGINEERS IN THE CERTIFICATION OF AIRCRAFT OR AIRCRAFT COMPONENTS FABRICATED FROM THESE ADVANCED MATERIALS. IN ADDITION, WE ARE DEVELOPING A LOW-COST PORTABLE NON-DESTRUCTIVE INSPECTION SYSTEM WHICH WILL ENSURE THE STRUCTURAL ADEQUACY OF ADVANCED FIBER COMPOSITE STRUCTURES DURING MANUFACTURE AND IN FIELD SERVICE. THE COMPLETION OF THIS SYSTEM IS SCHEDULED FOR FY83, AND IT IS EXPECTED THAT IT WILL BE USED BY BOTH INDUSTRY AND THE AIRLINES.

ALSO DURING FY-83, WE WILL INITIATE A PROGRAM TO EVALUATE THE IMPACT DAMAGE SENSITIVITY OF AIRFRAME PRIMARY STRUCTURES CONFIGURED FROM KEVLAR-EPOXY MATERIALS. THIS EFFORT IS SCHEDULED TO BE COMPLETED DURING 1984.

(VIEWGRAPH 19 OFF)

THIS FINAL ELEMENT IN THE AIRWORTHINESS AREA DEALS WITH THE COCKPIT, ALERT, AND THE WARNING SYSTEMS. THE NEED TO FUNCTIONALLY STANDARDIZE AND MINIMIZE THE VARIOUS "BELLS, WHISTLES, AND VISUALS" ASSOCIATED WITH COCKPIT WARNING DEVICES, IS ONE OF OUR ONGOING PROGRAMS. WE WILL BE DEVELOPING GUIDELINES FOR AN AUTOMATED AIRCRAFT MONITORING SYSTEM TO EVALUATE AIRCRAFT PERFORMANCE AND ASSIST THE FLIGHT CREW TO REACT PROMPTLY AND CORRECTLY TO AIRCRAFT MALFUNCTIONS OR FAILURES. HUMAN FACTORS IS A MAJOR CONSIDERATION IN THIS PROGRAM. UNDER SPONSORSHIP OF THE FAA, THE THREE MAJOR AIRFRAME MANUFACTURES, IN A COOPERATIVE EFFORT, ARE DEVELOPING SYSTEM CONCEPTS FOR A FLIGHT PHASE STATUS MONITOR.

THE FINAL SEGMENT OF MY BRIEFING DEALS WITH OUR AIRPORT PROGRAM, AND MORE SPECIFICALLY RUNWAY TRACTION, SNOW AND ICE REMOVAL AND WIND SHEAR.

OUR RUNWAY SURFACE TRACTION PROGRAM PRIMARILY ADDRESSES THE POTENTIAL REDUCTION IN RUNWAY FRICTION LEVELS ON WATER COVERED RUNWAYS. OUR PROGRAM INVOLVES RESEARCH AND DEVELOPMENT OF FRICTION MEASUREMENT TECHNIQUES AND IMPROVEMENTS OF RUNWAY SURFACE CONDITIONS TO ENHANCE AIRCRAFT BRAKING AND TO REDUCE THE CHANCES OF HYDROPLANING AND LOSS OF DIRECTIONAL CONTROL UNDER WET WEATHER CONDITIONS.

(VIEWGRAPH #20 ON)

OUR PROGRAM CURRENTLY INVOLVES TEST AND EVALUATION OF VARIOUS RUNWAY SURFACE TREATMENTS, WHICH INCLUDE GROOVING TECHNIQUES. THIS RESEARCH IS PERFORMED USING THE NAVAL AIR ENGINEERING CENTER'S DYNAMIC TEST TRACK LOCATED AT LAKEHURST, NEW JERSEY.

(VIEWGRAPH #20 OFF VIEWGRAPH #21 ON)

THE OPERATION OF THIS FACILITY CAN BE SEEN IN THE VIDEO FILM.

(VIEWGRAPH #21 OFF VIDEO ON)

THE TEST PROCESS INVOLVES A JET TEST VEHICLE WHICH ACCELERATES AND BRAKES AN AIR CARRIER AIRCRAFT TIRE WHEEL ASSEMBLY IN A TRACK WITH CONTROLLED WATER DEPTH CONDITIONS. YOU WILL NOTE THE WHEEL CHANGING FROM NORMAL BRAKING TO A HYDROPLANING CONDITION AS IT LEAVES A GROOVED SURFACE AND ENTERS UPON A NONGROOVED SURFACE. I MIGHT NOTE THAT WE RECENTLY INSTALLED A SERIES OF TEST CONFIGURATION GROOVES IN OUR PRIMARY RUNWAY AT THE FAA TECHNICAL CENTER. THIS WILL ALLOW FOR A CERTAIN DEGREE OF IN-SERVICE EVALUATION OF THE EFFECTS OF GROOVES, AS A SUPPLEMENT TO THE DYNAMIC TEST TRACK PROCEDURES.

(VIDEO OFF VIEWGRAPH #22 ON)

WE HAVE DEMONSTRATED THE ENHANCEMENTS PROVIDED BY RUNWAY GROOVING. WE HAVE ALSO IDENTIFIED THE COST/PERFORMANCE TRADEOFF ASSOCIATED WITH CONVENTIONAL GROOVING TECHNIQUES. AN EXPERIMENTAL PERCUSSIVE GROOVING TECHNIQUE HAS BEEN IDENTIFIED AND HAS A COST SAVING POTENTIAL IN EXCESS OF 25%. THIS TECHNIQUE IS CURRENTLY BEING TESTED.

FUTURE PLANS IN THIS AREA CONSIDER DESIGN, DURABILITY, AND MAINTENANCE OF ALTERNATE SURFACE TREATMENTS, TIRE/RUNWAY INTERFACE PHENOMENA, AND THE DESIGN OF A SYSTEM FOR MONITORING RUNWAY CONDITIONS.

(VIEWGRAPH #22 OFF VIEWGRAPH #23 ON)

WITH RESPECT TO SNOW AND ICE CONTROL, WE HAVE DEVELOPED AIRPORT MAINTENANCE AND GROUND OPERATIONS PROCEDURES TO IMPROVE AIRPORT OPERATING EFFICIENCY AND SAFETY. AIRPORT ADVISORY CIRCULARS HAVE BEEN ISSUED WHICH RECOMMEND SNOW AND ICE REMOVAL PROCEDURES BASED ON THE COMPLEXITY AND NATURE OF RUNWAY OPERATIONS.

(VIEWGRAPH #23 OF)

UNDER A SEPARATE PROJECT, WE HAVE INVESTIGATED THE POTENTIAL OF A HEATED RUNWAY SURFACE TO PRECLUDE SNOW AND ICE BUILDUP. OF THE THREE SYSTEMS INVESTIGATED, ELECTRICAL, STEAM, AND SOLAR HEAT, THE SOLAR SYSTEM APPEARS TO BE THE MOST COST/BENEFICIAL AND IS THE MOST EFFICIENT IN THE UTILIZATION OF THE NATION'S ENERGY RESOURCES. HOWEVER, WHILE IT IS TECHNICALLY FEASIBLE TO HEAT A RUNWAY SURFACE, THE CAPITAL AND RECURRING COSTS FOR SUCH AN UNDERTAKING ARE A DETERRENT TO IMPLEMENTATION AT THIS TIME. INSTALLATION COSTS ON A SINGLE RUNWAY, FOR EXAMPLE, RUN IN THE AREA OF $10M, BASED ON A 1975 STUDY.

FINALLY, IN THE AREA OF WIND SHEAR PHENOMENON, THE FAA ESTABLISHED SIX TASKS:

1. WIND SHEAR CHARACTERIZATION
2. HAZARD DEFINITION
3. WIND SHEAR DATA MANAGEMENT

4. GROUND-BASED WIND SHEAR DETECTION SYSTEMS
5. INTEGRATION OF WIND SHEAR SYSTEMS AND DATA INTO THE NATIONAL AIRSPACE SYSTEM
6. AIRBORNE WIND SHEAR DEVELOPMENT EFFORTS

THE FIRST THREE TASKS: WIND SHEAR CHARACTERIZATION, HAZARD DEFINITION, AND WIND SHEAR DATA MANAGEMENT HAVE BEEN COMPLETED.

(VIEWGRAPH #24 ON)

ONE APPROACH TO GROUND-BASED WIND SHEAR DETECTION IS A LOW-LEVEL WIND SHEAR ALERT SYSTEM, WHICH IS INSTALLED AT SEVERAL MAJOR AIRPORTS IN THE U.S. THIS SYSTEM COMPARES THE WIND DIFFERENCE BETWEEN LOCATIONS AROUND THE PERIMETER OF AN AIRPORT AND A CENTERFIELD LOCATION, AND IF A VECTOR DIFFERENCE OF 15 KNOTS OR MORE IS MEASURED, AN ALARM IS TRIGGERED IN THE TOWER, WHICH IN TURN, CAN NOTIFY THE PILOTS OF THIS EVENT. CURRENT PLANNING CALLS FOR PROCUREMENT OF 60 ADDITIONAL SYSTEMS FOR AIRPORTS.

(VIEWGRAPH #24 OFF VIEWGRAPH #25 ON)

TESTS ARE ALSO PRESENTLY UNDERWAY TO DETECT AND MEASURE WIND SHEAR IN THE TERMINAL AREA USING AN ASR-8 DOPPLER RADAR TECHNIQUE TO OBTAIN WIND SHEAR AND DIRECTION. TASK 5, INTEGRATION OF WIND SHEAR SYSTEMS AND DATA INTO NAS, IS CURRENTLY AN ONGOING EFFORT.

(VIEWGRPAH #25 OFF, VIEWGRAPH #26 ON)

THE SIXTH AND LAST TASK DEALS WITH OUR WORK ON AIRBORNE WIND SHEAR DETECTION AND MEASUREMENT SYSTEMS. ACCOMPLISHMENTS TO DATE INCLUDE FLIGHT TEST EVALUATION OF AIRCRAFT GROUND-SPEED MEASUREMENT SYSTEMS AND FLIGHT DEMONSTRATION OF VARIOUS COCKPIT DISPLAYS USING PILOT AIDING CONCEPTS. AS A RESULT OF THESE EFFORTS, WIND SHEAR PROFILES FOR FLIGHT SIMULATION TRAINING HAVE BEEN PROVIDED TO THE AIRLINES.

(VIEWGRAPH #26 OFF)

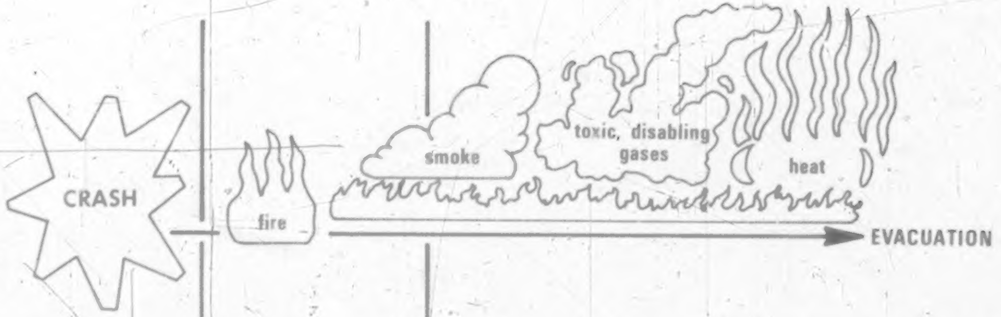
GENTLEMAN:

THAT CONCLUDES MY PRESENTATION OF OUR AIRCRAFT AND AIRPORT SAFETY PROGRAMS. I WOULD LIKE TO REPEAT THAT I HAVE PRESENTED SPECIFIC ELEMENTS OF THESE PROGRAMS IN RESPONSE TO YOUR REQUEST. SHOULD YOU DESIRE A COMPLETE REVIEW OF ALL ELEMENTS OF THE PROGRAMS, I WILL BE HAPPY TO PROVIDE THAT BRIEFING AT YOUR CONVENIENCE. MANY OF THE EFFORTS I HAVE DESCRIBED ARE CONDUCTED AT THE TECHNICAL CENTER, AND WE WOULD WELCOME A VISIT FROM YOU SO YOU CAN SEE THEM PERFORMED "IN REAL TIME."

THANK YOU.

VIEWGRAPHS USED DURING HEARING

POST-CRASH SURVIVAL


CRASH
fire
smoke
toxic, disabling gases
heat
EVACUATION

Structural Crash-worthiness

- CRASH RESISTANT FUEL SYSTEMS
- SEATS/RESTRAINT SYSTEMS

Fire Prevention

- ANTI-MISTING FUELS

Cabin Fire Safety

- INTERIOR MATERIALS
- EMERGENCY LIGHTING
- EVACUATION SLIDES
- FIRE EXTINGUISHMENT

IMPROVE OCCUPANT SURVIVABILITY

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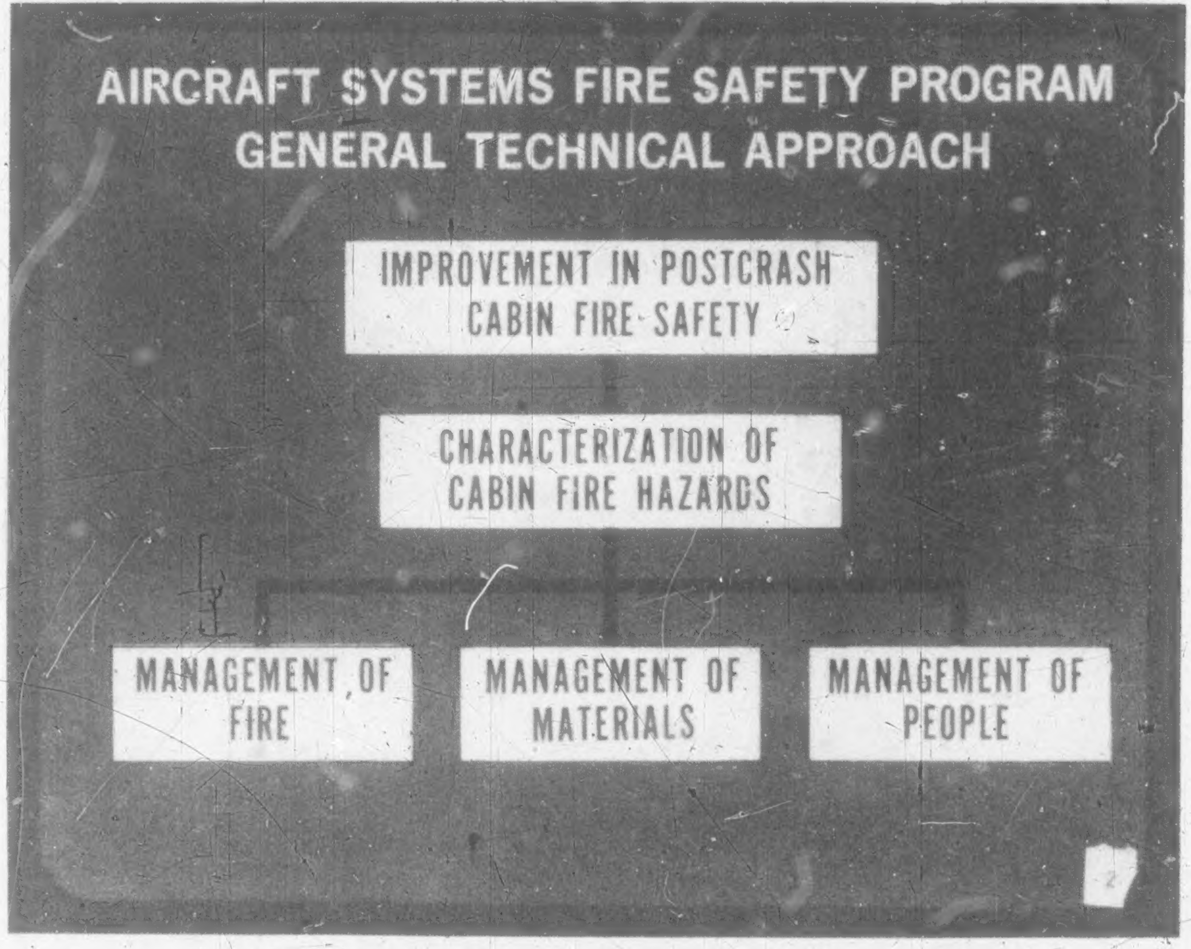


AIRCRAFT SYSTEMS FIRE SAFETY PROGRAM
GENERAL TECHNICAL APPROACH

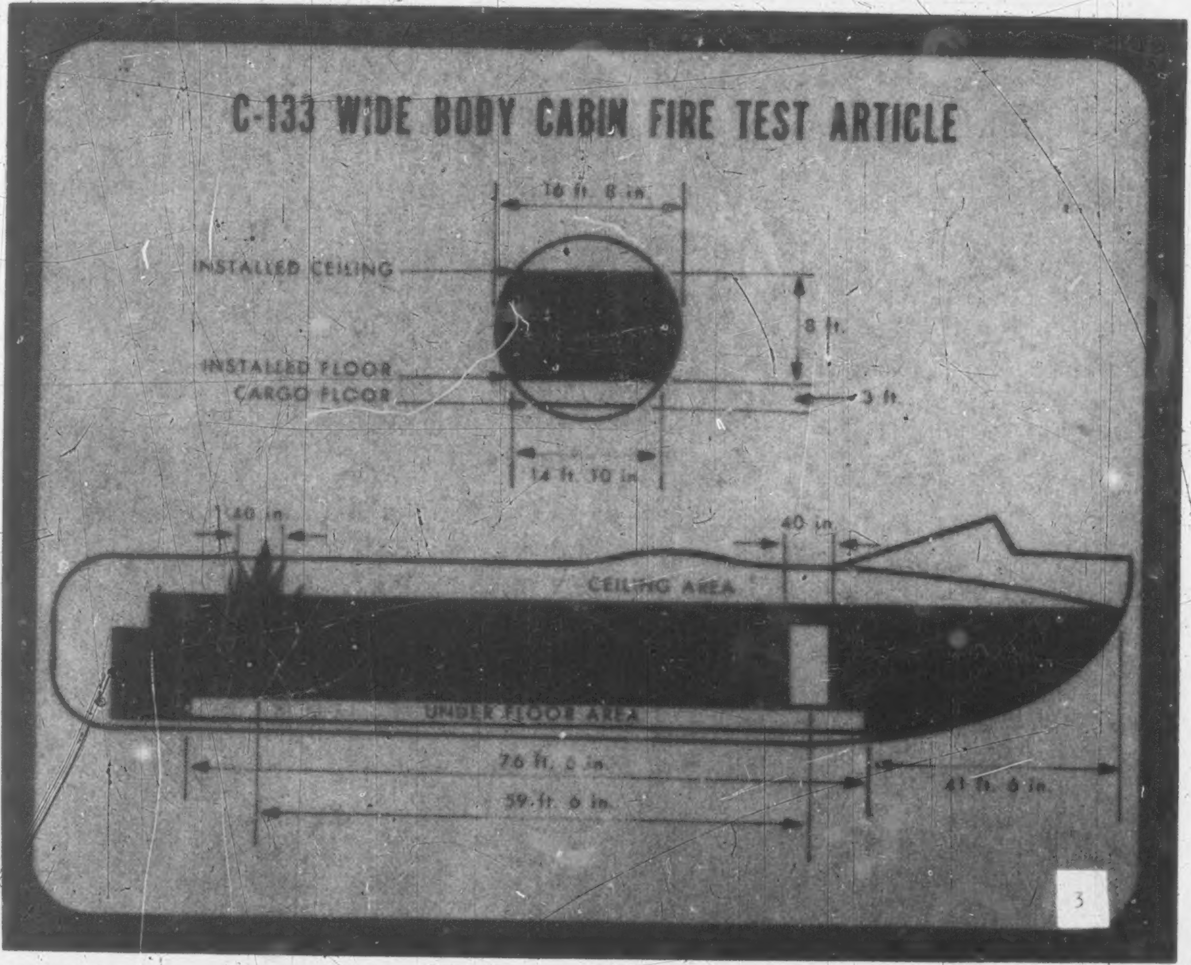
IMPROVEMENT IN POSTCRASH CABIN FIRE SAFETY

CHARACTERIZATION OF CABIN FIRE HAZARDS

MANAGEMENT OF FIRE

MANAGEMENT OF MATERIALS

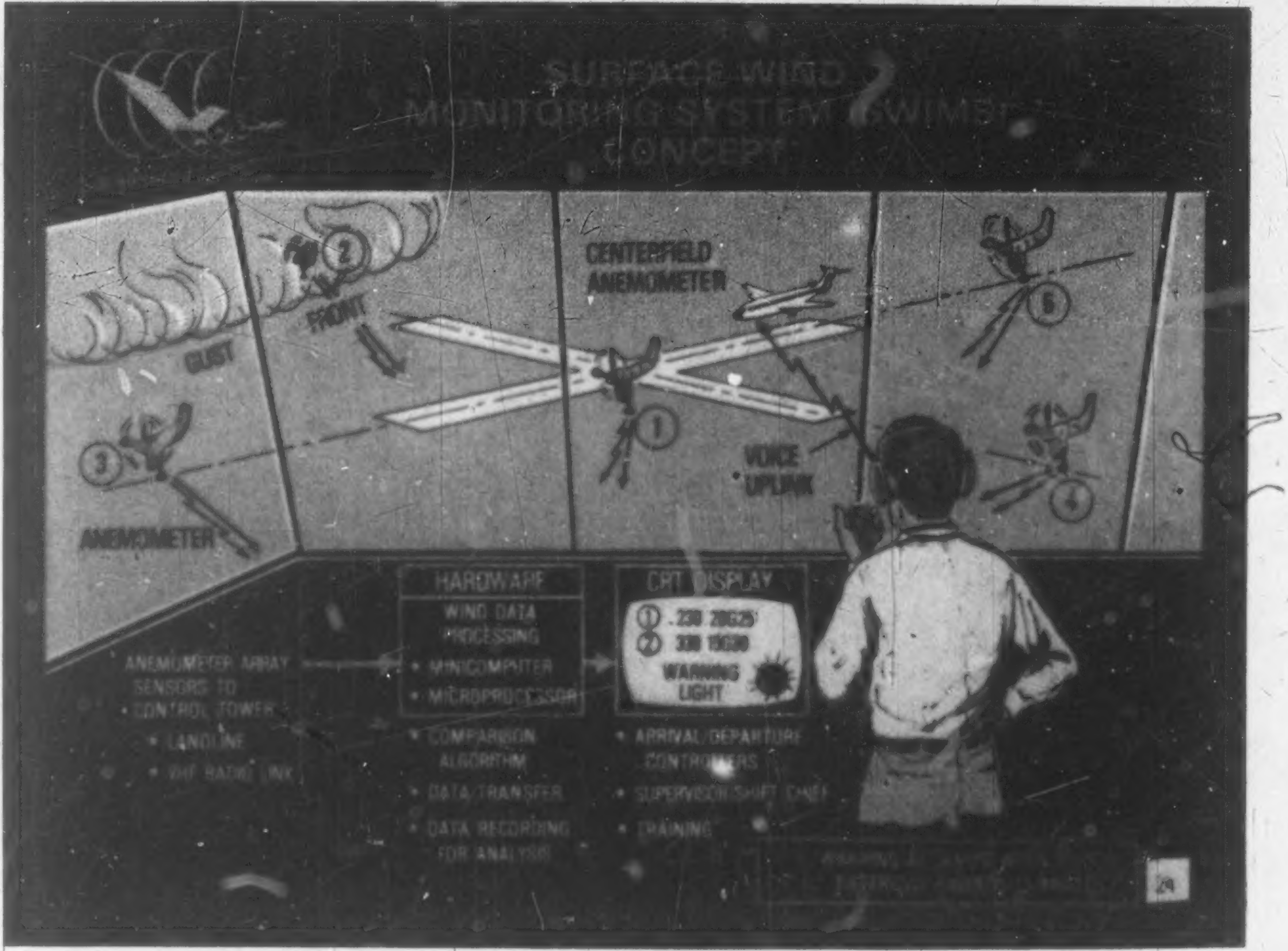
MANAGEMENT OF PEOPLE



C-133 WIDE BODY CABIN FIRE TEST ARTICLE

16 ft. 8 in.
INSTALLED CEILING
8 ft.
INSTALLED FLOOR
CARGO FLOOR
3 ft.
14 ft. 10 in.
40 in.
40 in.
CEILING AREA
UNDER FLOOR AREA
76 ft. 0 in.
41 ft. 6 in.
59 ft. 6 in.
3

SURFACE WIND MONITORING SYSTEM (SWIMS) CONCEPT


GUST
FRONT
CENTERFIELD ANEMOMETER
VOICE UPLINK
ANEMOMETER
①
②
③
④
⑤
CRT DISPLAY
① .230 20G25
② 330 15G30
WARNING LIGHT

ANEMOMETER ARRAY SENSORS TO CONTROL TOWER
- LANDLINE
- VHF RADIO LINK

HARDWARE

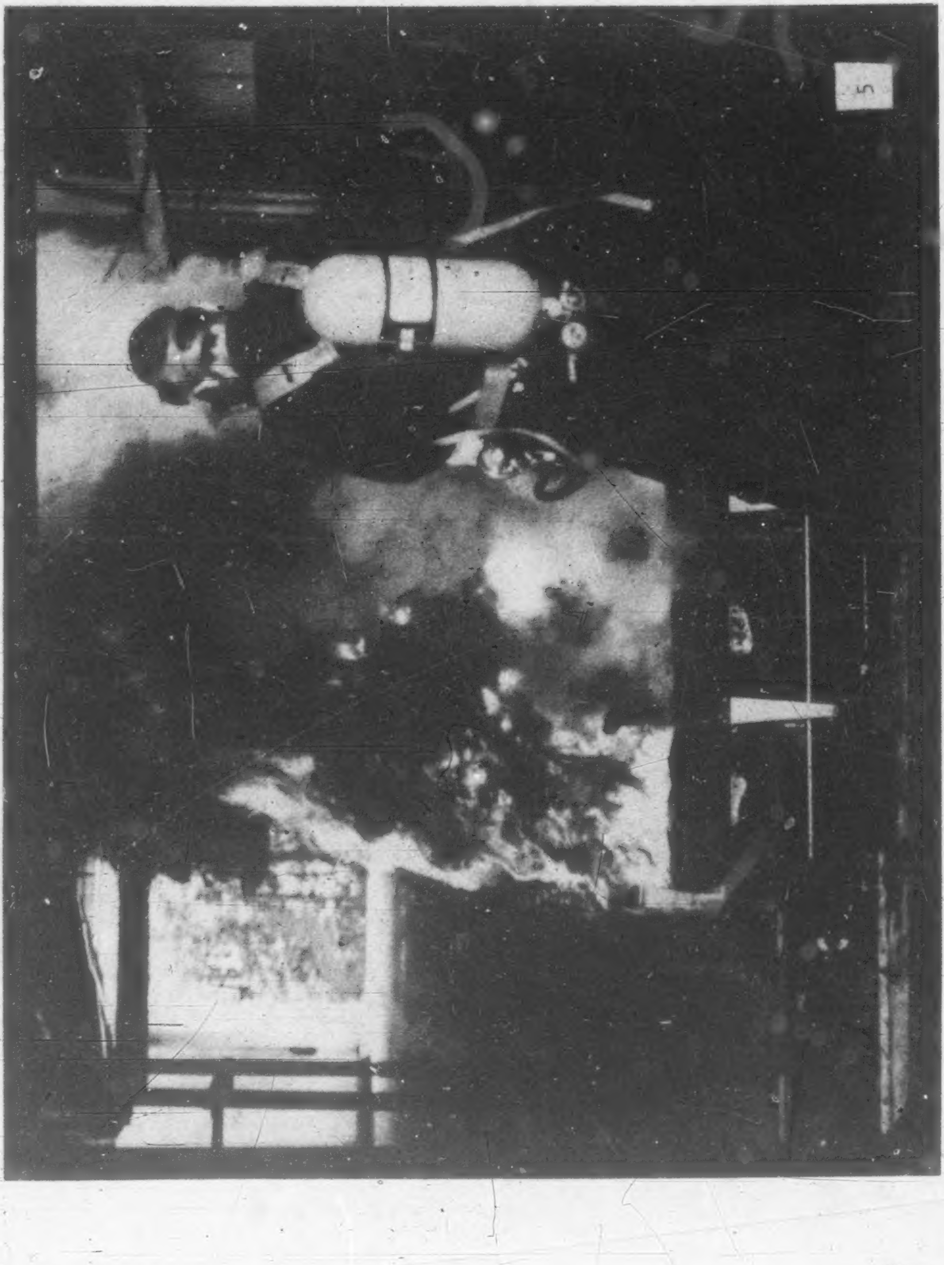
WIND DATA PROCESSING

- MINICOMPUTER
- MICROPROCESSOR
- COMPARISON ALGORITHM
- DATA/TRANSFER
- DATA RECORDING FOR ANALYSIS

CRT DISPLAY

- ARRIVAL/DEPARTURE CONTROLLERS
- SUPERVISOR/SHIFT CHIEF
- TRAINING

FIREWORTHY AIRCRAFT SEAT CUSHIONS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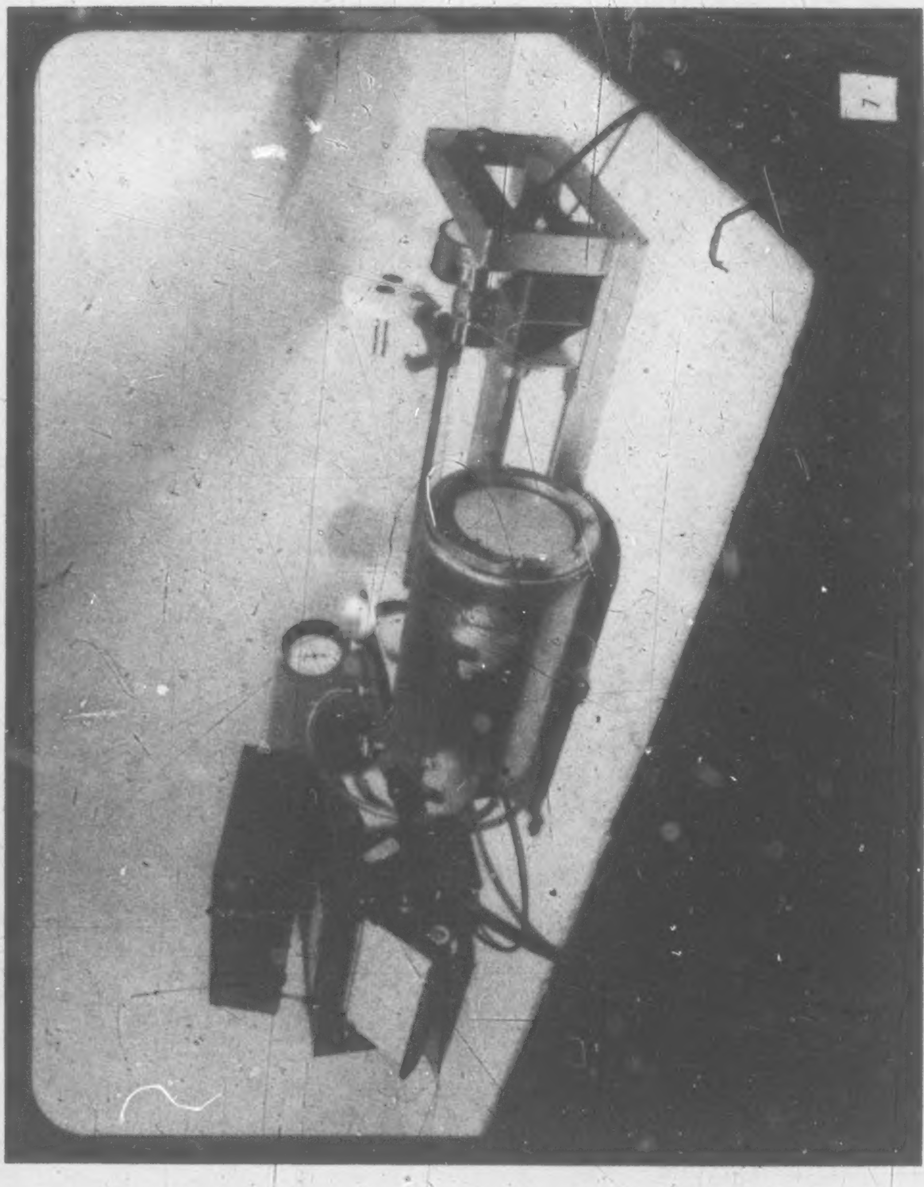
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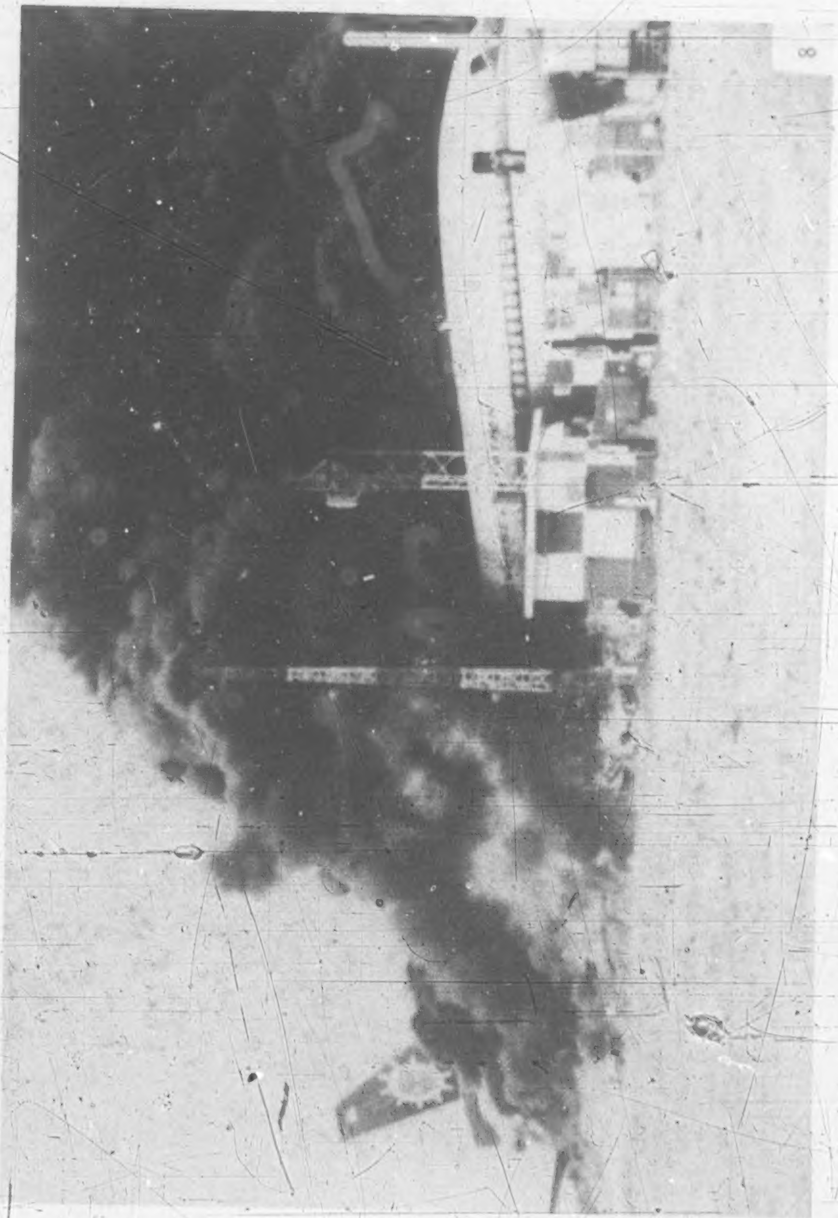
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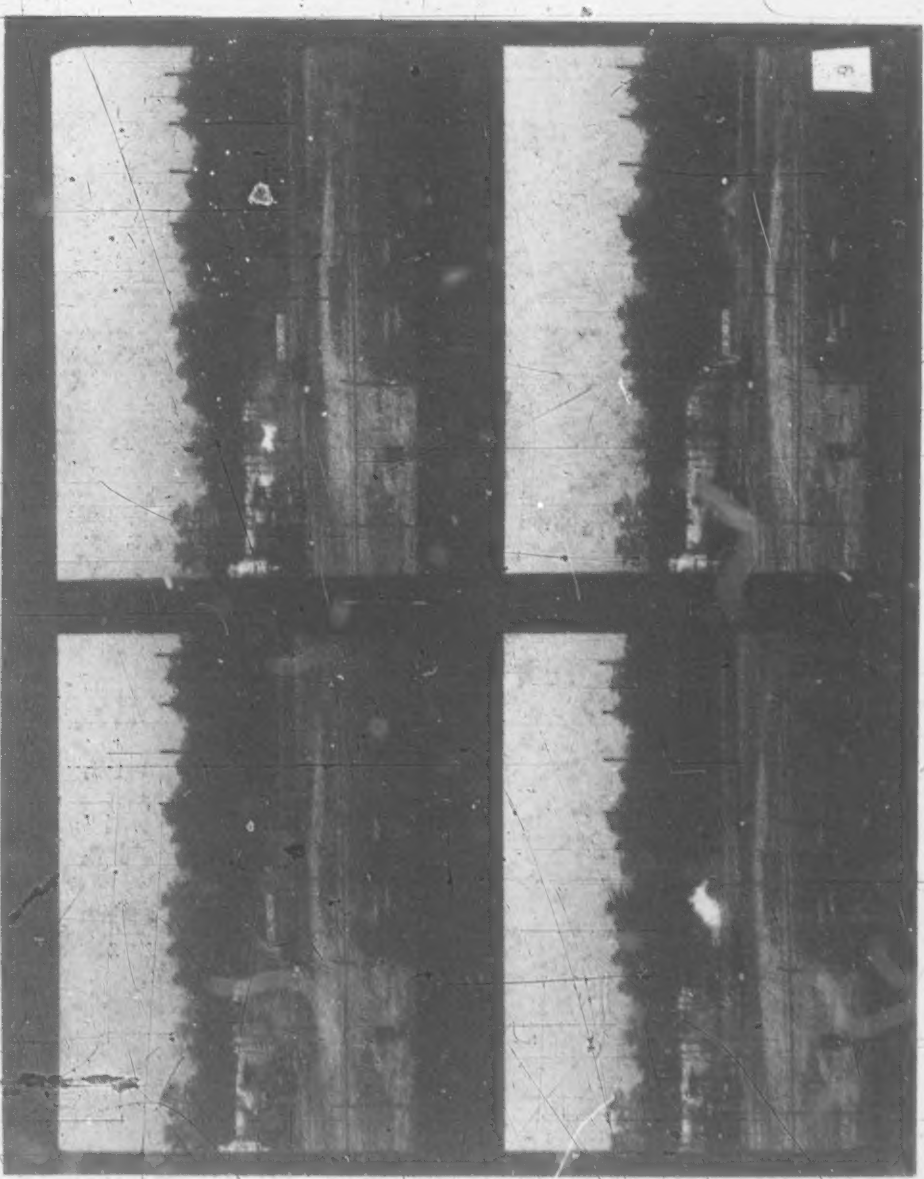

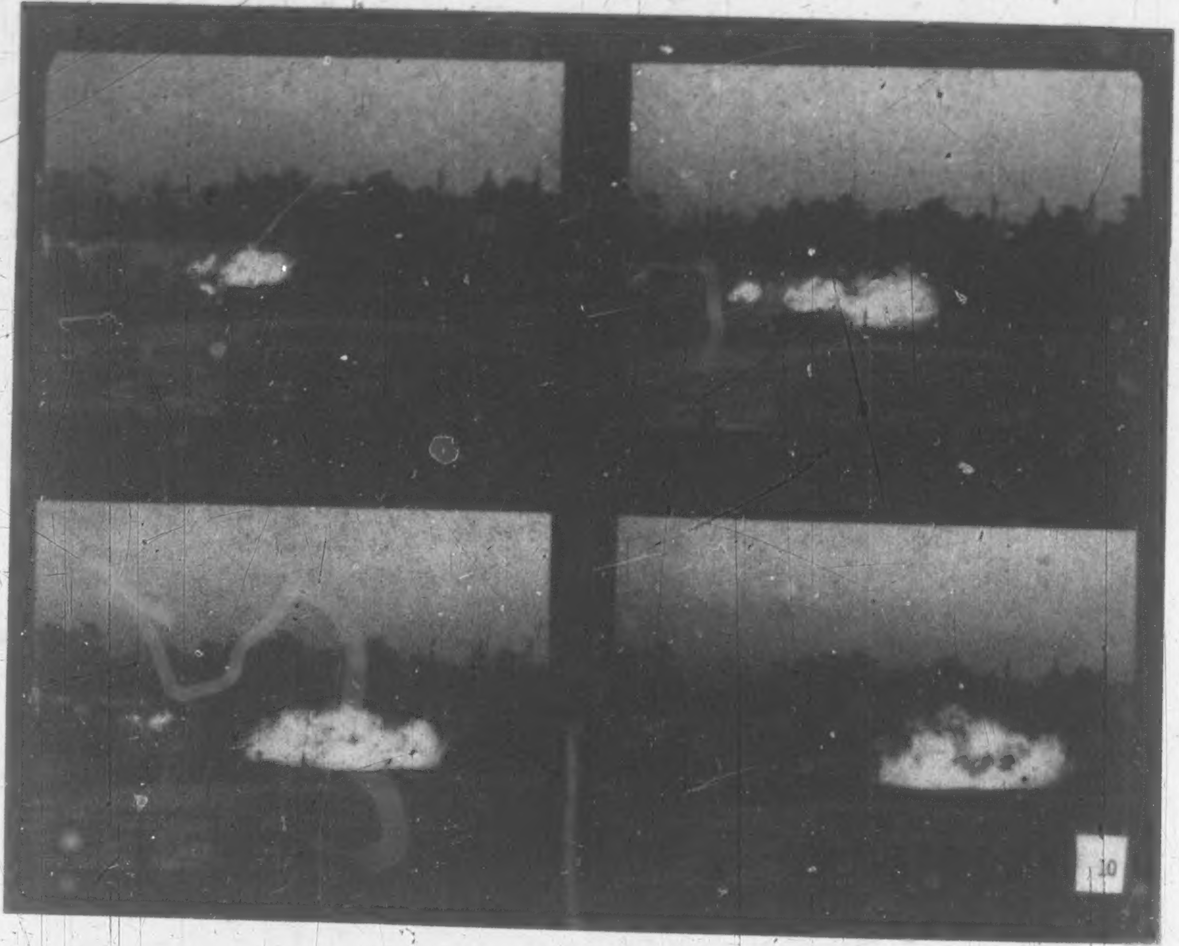
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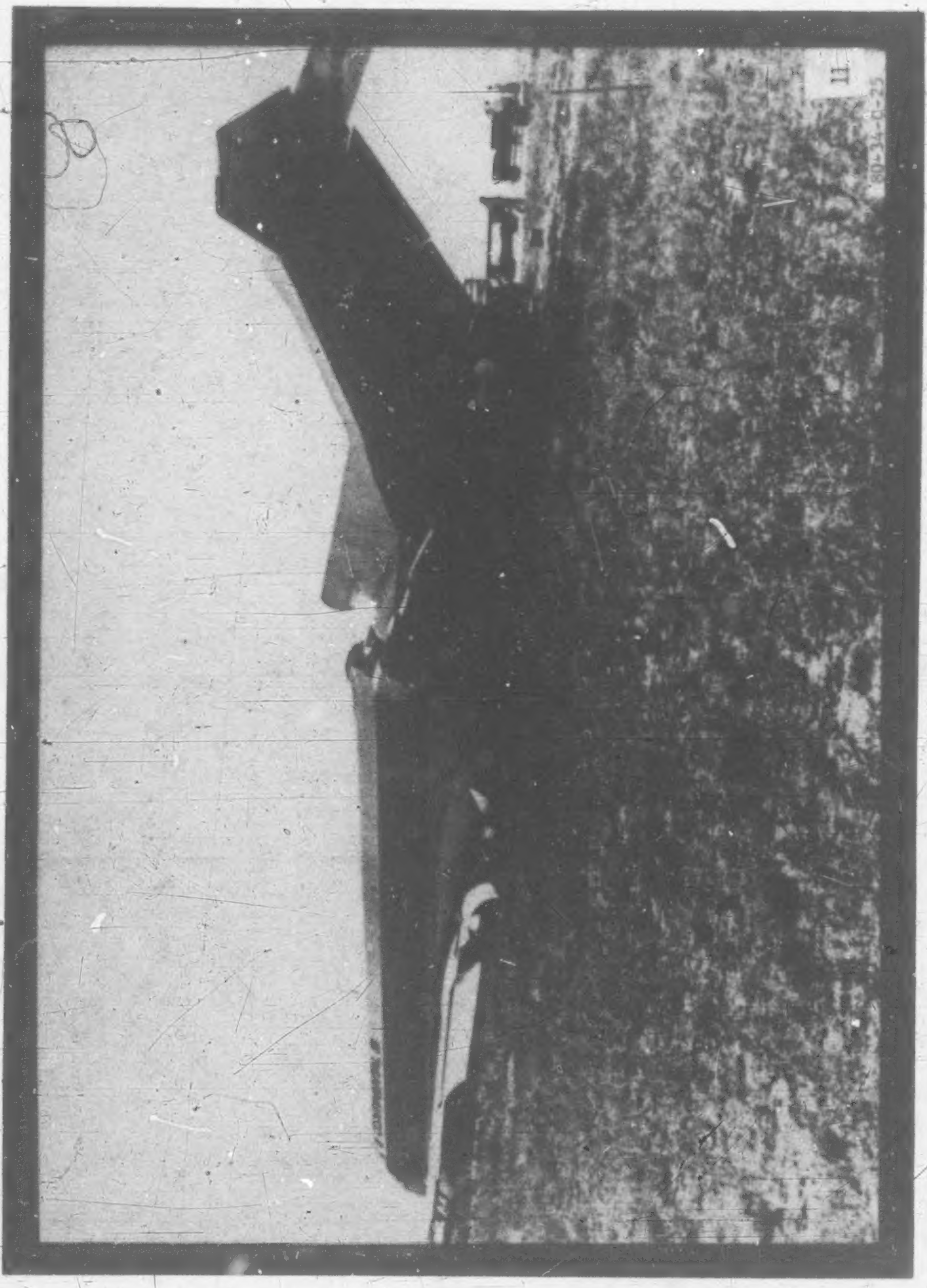
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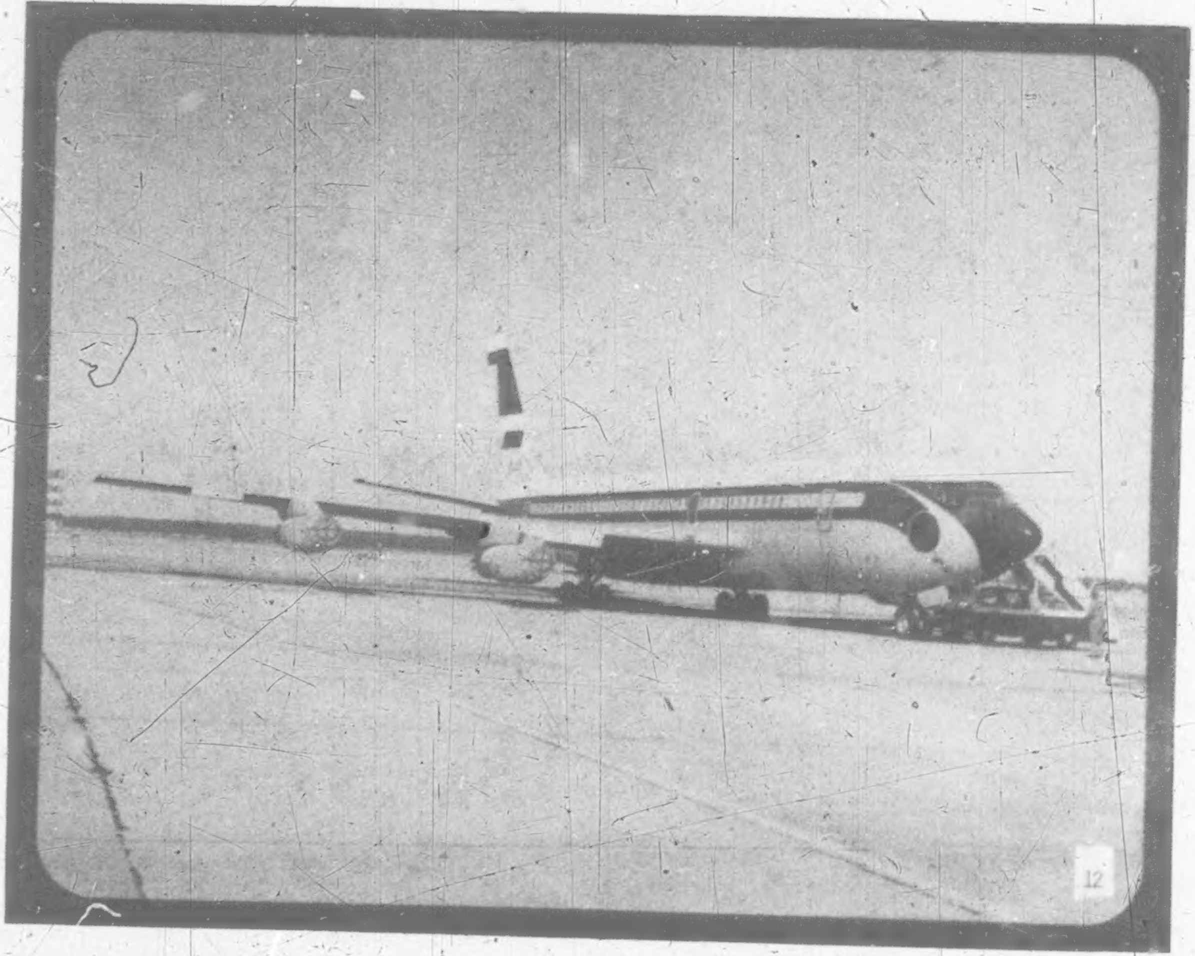
80-34-6-25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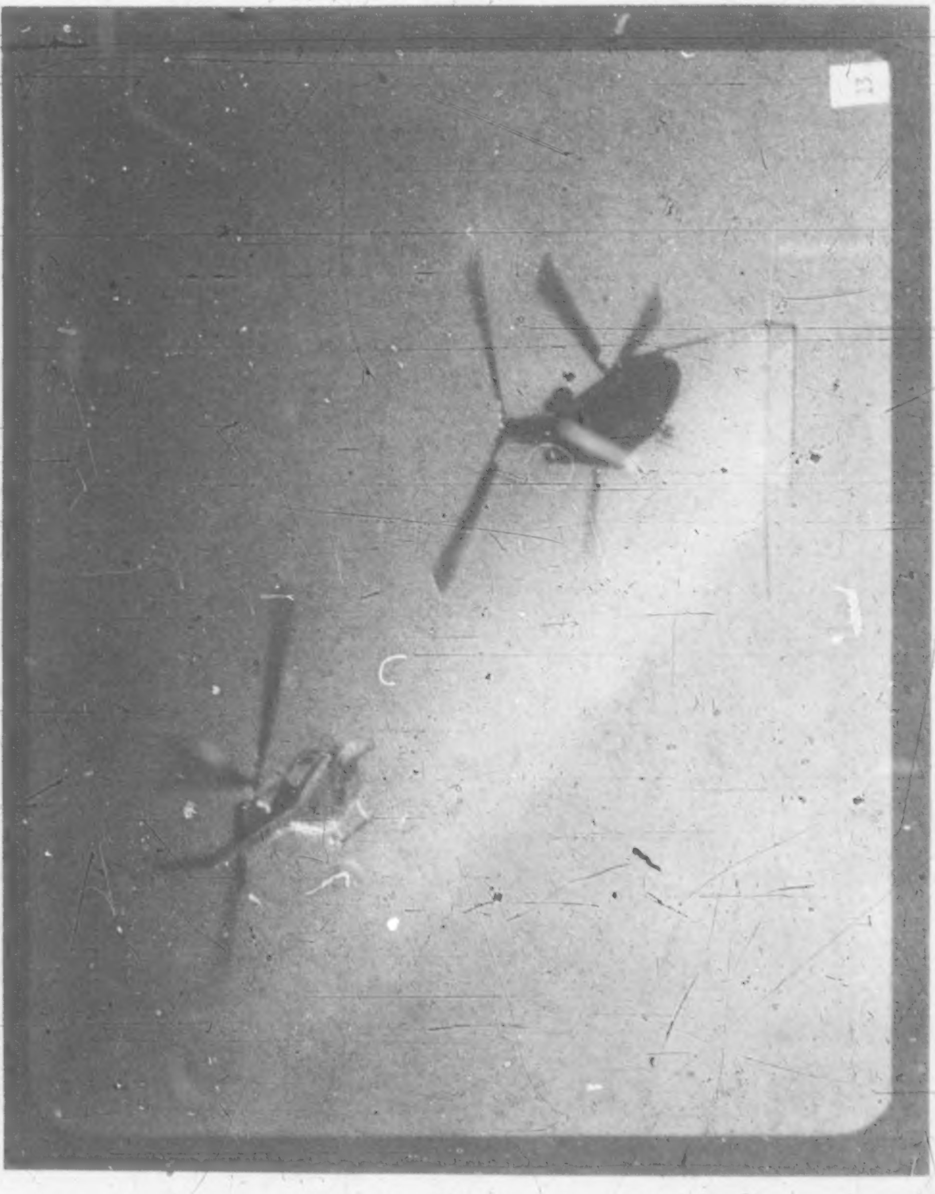

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SIKORSKY76™
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1981 Piper Saratoga SP
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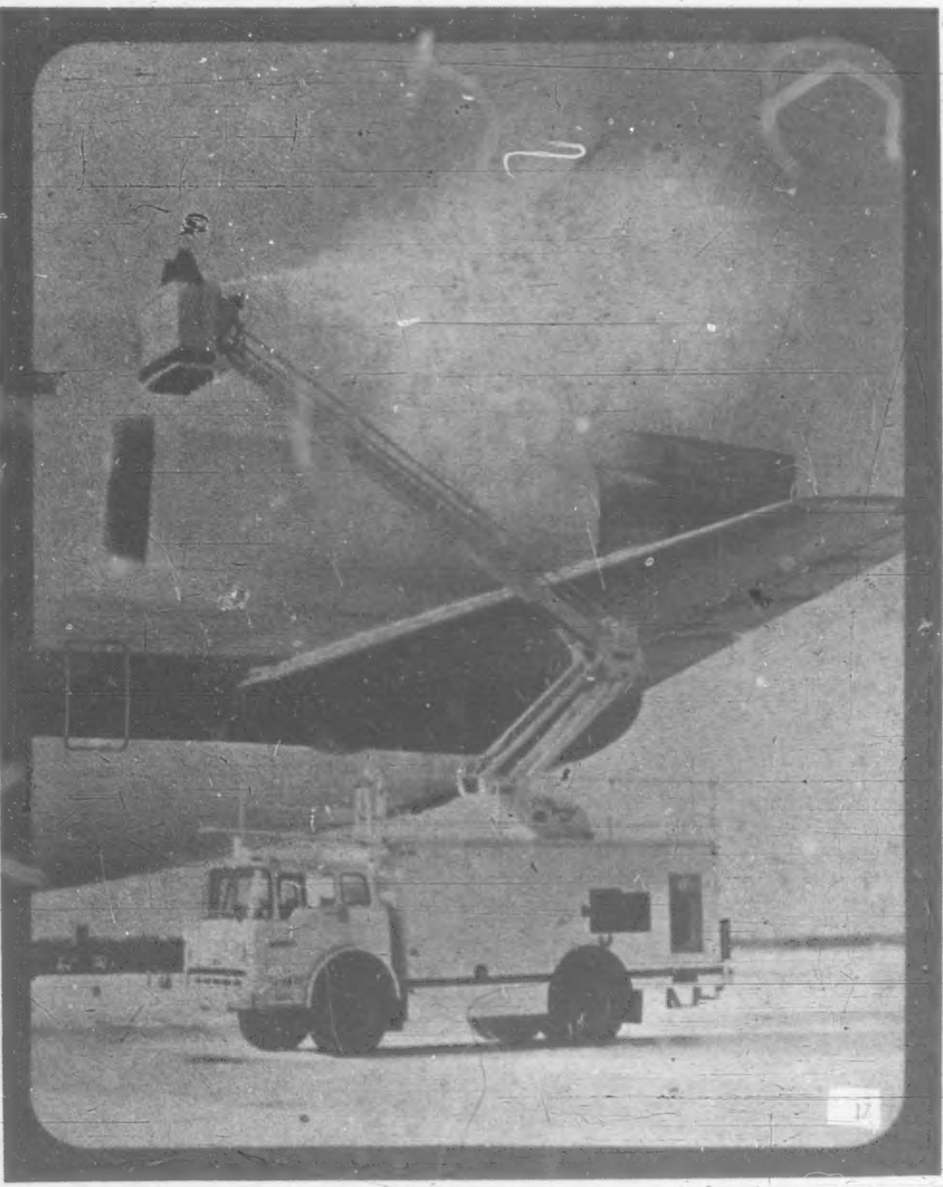

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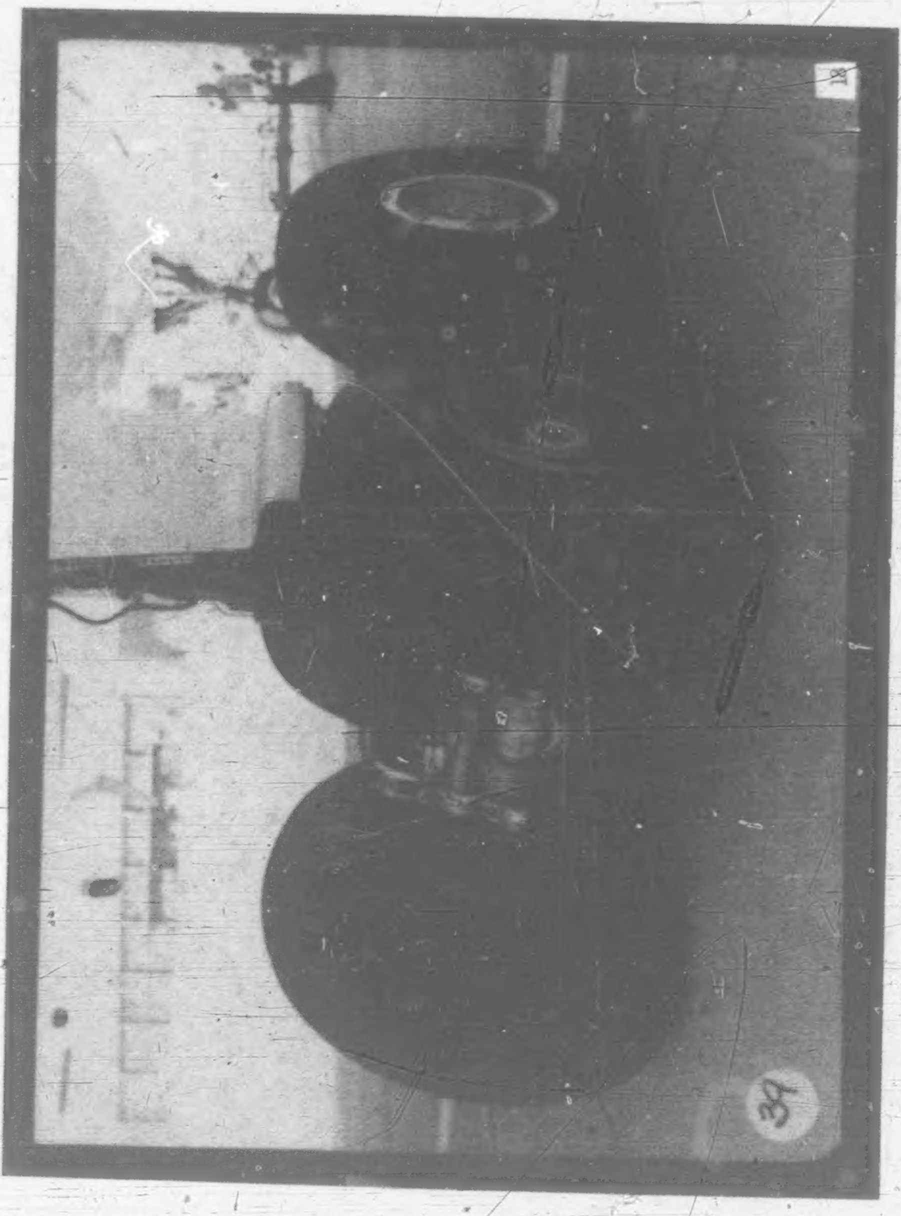
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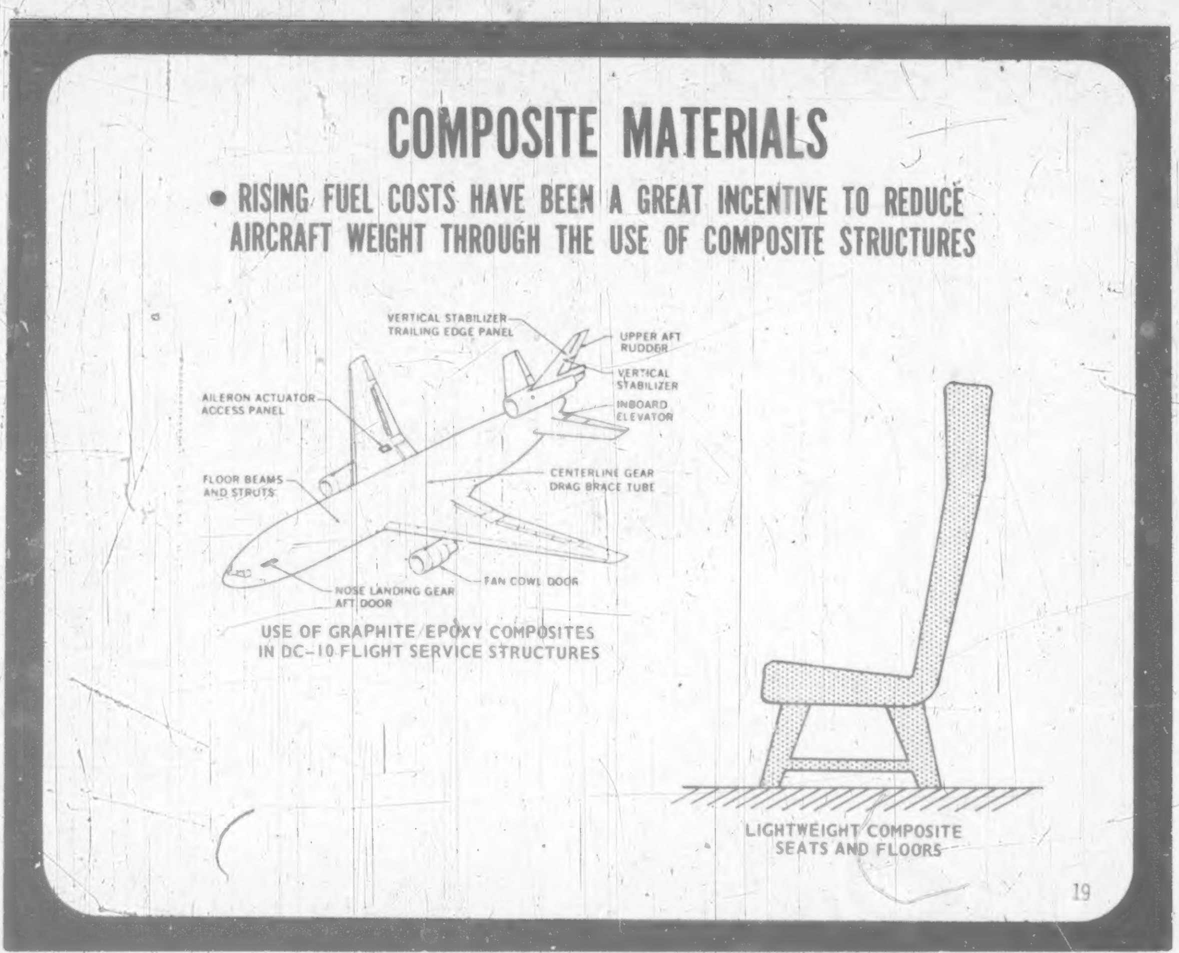


COMPOSITE MATERIALS

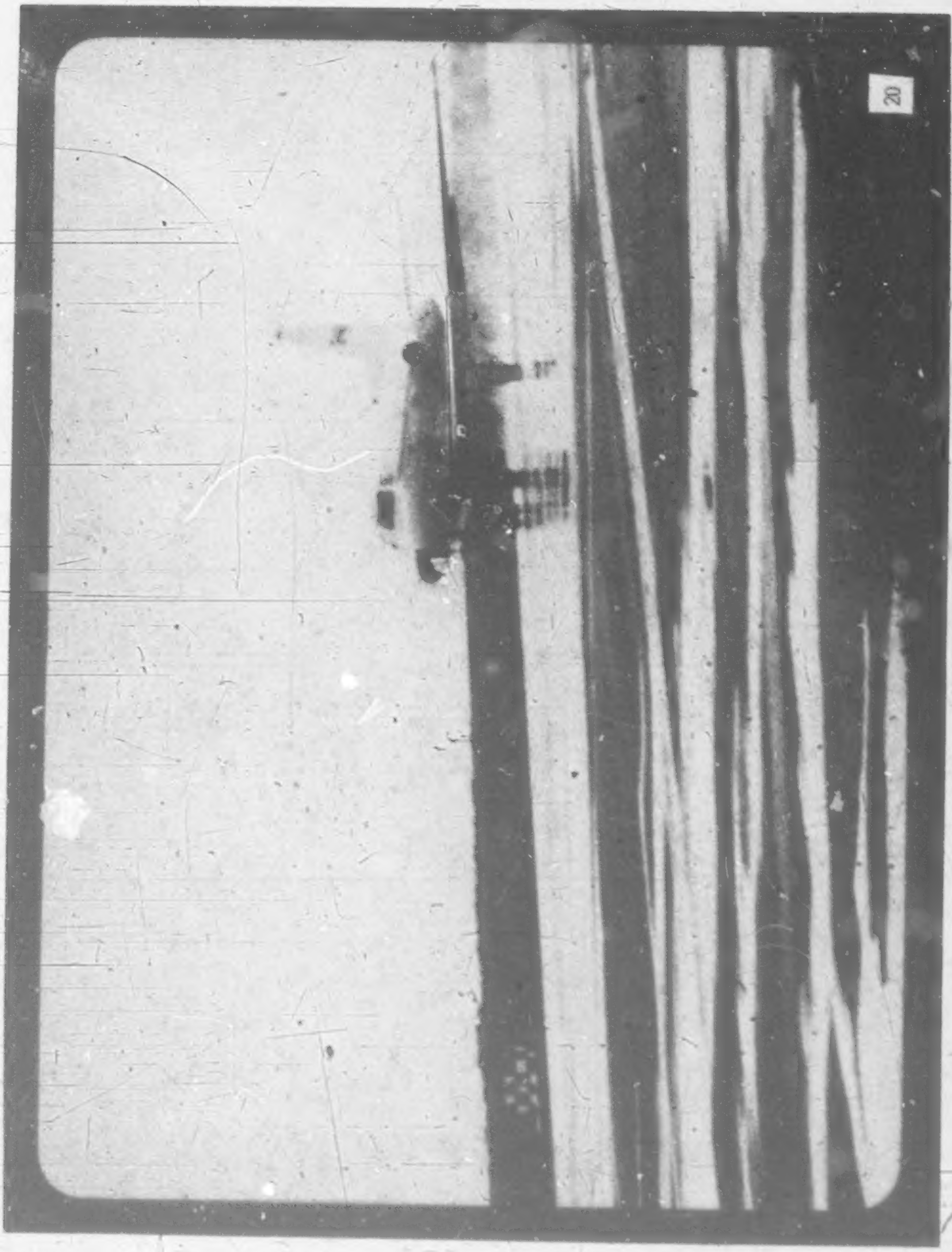
- RISING FUEL COSTS HAVE BEEN A GREAT INCENTIVE TO REDUCE AIRCRAFT WEIGHT THROUGH THE USE OF COMPOSITE STRUCTURES

VERTICAL STABILIZER TRAILING EDGE PANEL
UPPER AFT RUDDER
VERTICAL STABILIZER
INBOARD ELEVATOR
AILERON ACTUATOR ACCESS PANEL
FLOOR BEAMS AND STRUTS
CENTERLINE GEAR DRAG BRACE TUBE
FAN COWL DOOR
NOSE LANDING GEAR AFT DOOR

USE OF GRAPHITE/EPOXY COMPOSITES IN DC-10 FLIGHT SERVICE STRUCTURES

LIGHTWEIGHT COMPOSITE SEATS AND FLOORS

19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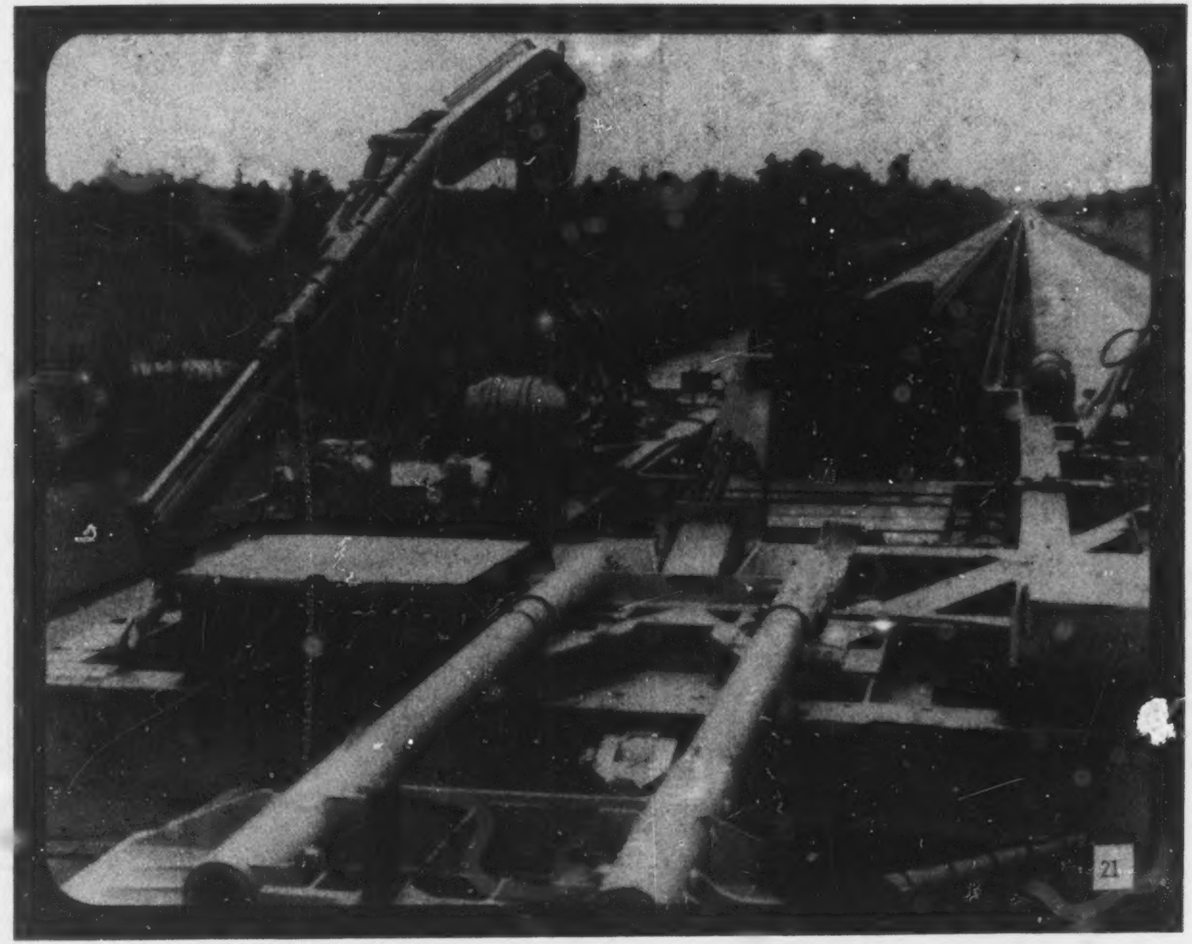
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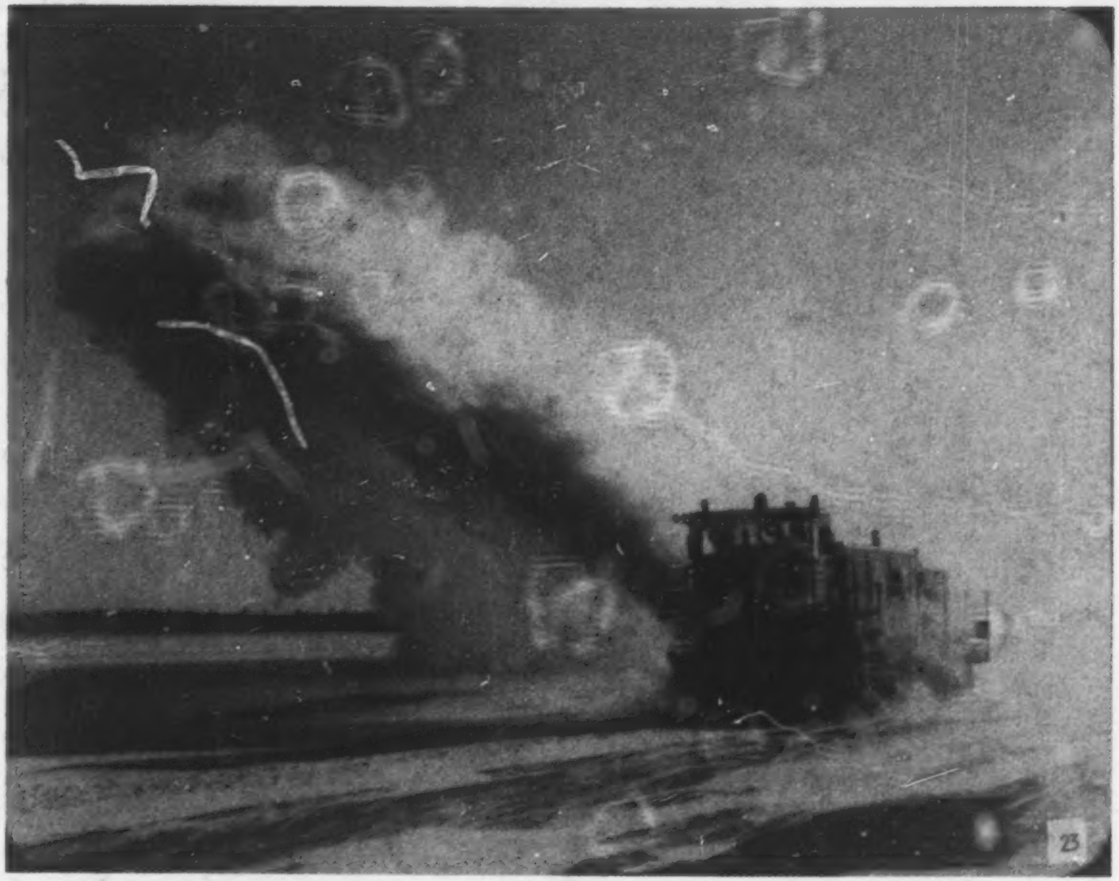
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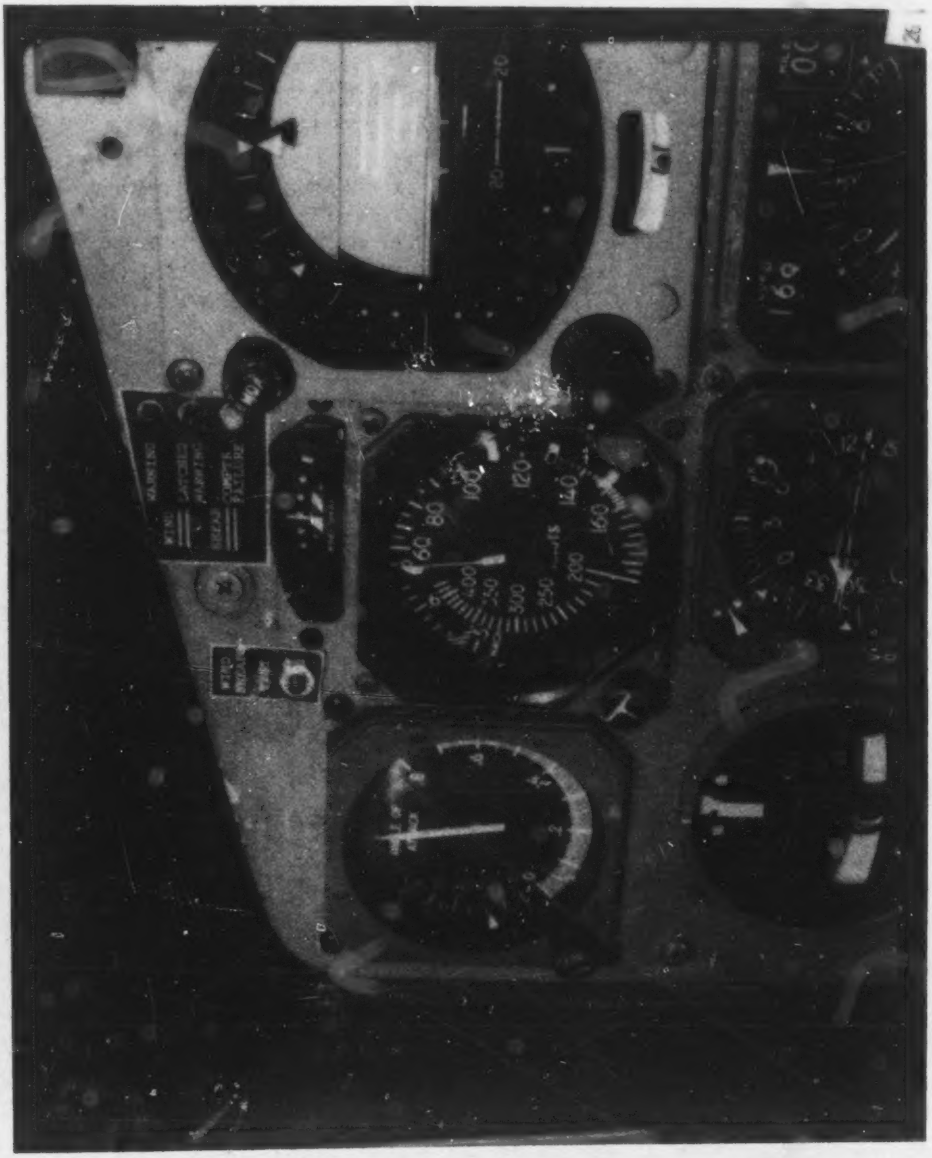

Mr. **Glickman**. Thank you, Dr. Koenke and Mr. Albrecht.

I am sure we will have some questions.

Mr. Albrecht, General Ralph of the Air Transportation Association, who is going to testify later today, will testify that the FAA's R. & D. activities, many of which you showed there on your viewgraphs, will come to a virtual standstill as a result of budget cuts. I wonder if you care to comment on that?

Mr. **Albrecht**. I think that is a severe exaggeration, Mr. Chairman. I believe Mr. Helms has indicated to the committee the kinds of expenditures necessary to support not only this program but the national airspace plan which has been submitted to Congress. And we expect that the total plan will be supported and will be carried out.

Mr. **Glickman**. I realize we have talked about the National Airspace Plan, and there is a alot of R. & D. that needs to be done, but specifically on the programs you were talking about here—icing, human factors, antimisting, crashworthiness seats—are you going to be spending as much money next year as you did this year?

Mr. **Albrecht**. We will be spending much more next year, Mr. Chairman. We expect to—but let me qualify that.

This year has been a bad budget year. This particular program did lose a substantial amount of support.

Mr. **Glickman**. You are talking about the whole general——

Mr. **Albrecht**. No, the F.E. & D. appropriation based on congressional action.

We expect that will be restored next year and our program runs at the level of about $20 million per year. This year we are spending about $9 million. So this year has been a problem, but I think in the future that situation should not exist.

Mr. **Glickman**. You say $9 million for fiscal 1982 on, again, the kinds of functions that were raised—basically in the operation of the tech center in Atlantic City and related functions?

Mr. **Albrecht**. Yes, and the associated contract work. But I need to point out, Mr. Glickman, that we have reviewed our progress this year very carefully and in the documents we submitted to the committee you will see that we are on schedule with all of our congressional commitments.

Mr. **Glickman**. OK, in terms of dollar amount, though, you say that you are going to try to spend about $20 million next year, fiscal 1983. You will spend $9 million in fiscal 1982. What did you spend in fiscal 1981?

Mr. **Albrecht**. Around $21 million.

Mr. **Glickman**. $21 million. So there was a dramatic reduction in this year's expenditures?

Mr. **Albrecht**. This year. Yes, sir, this year. We expect that's not a pattern.

Mr. **Glickman**. I know the Administrator well. I'm sure that he has a serious intention to continue the R. & D. activities, particularly air safety research, as a high priority. I don't think that the public will tolerate any dramatic reductions in those expenditures in the years to come.

Mr. **Albrecht**. There is no question of the administrator's support, Mr. Glickman. We hope Congress supports it.

Mr. **Glickman**. OK.

I would like to ask questions on the specific areas of research. The first one is icing. I was amazed to find out during the Air Florida crash that there were no standards for the specific mix of glycol and water that have been issued by the FAA. So, therefore, the airlines have complete and total discretion as to what percentage of glycol to use. I also noticed that the percentages—I think it was American Airlines that said what they thought they used wasn't actually the percentage that was in fact used. You talked about a lot of the icing research when an airplane is flying, and I know that needs to be done, but how come there have been no standards in the whole issue of deicing an airplane on the ground in terms of what kind of materials to use, the optimum mix of glycol and water, and other related issues?

Mr. **Albrecht**. We have some difficulty with that question, Mr. Chairman, because basically our task is research and development, and the issuances of standards is a regulatory procedure. It is carried out under Mr. Luffsey, the Associate Administrator for Aviation Standards, so I can't answer directly why there have been no standards. We can describe the R. & D. that we do to support Mr. Luffsey, who is our principal customer.

Mr. **Glickman**. Well, what are you doing in terms of R. & D. on deicing solution?

Dr. **Koenke**. Back in February 1981 we initiated a program to look at ethylene glycol, the mixture, and the optimum mixture to be used as a function of precipitation level, type of precipitation, how long it would be effective as an anti-icing versus a deicing technique, what the mixture should be for deicing and then what the mixture should be for anti-icing. That's included in a program plan that we have developed over the past year and is now in coordination with AVS.

Mr. **Glickman**. When did you start this program?

Dr. **Koenke**. February 1981.

Mr. **Glickman**. OK.

As I understand it, the glycol solution is what we have been using in this country from time immemorial to deice an airplane.

Dr. **Koenke**. Yes, sir.

Mr. **Glickman**. And I understand its primary function is as a deicer, not as an icing preventative. Is that a fair statement?

Dr. **Koenke**. It can be used as an anti-icing agent, I believe, if it is used at 100-percent quantity.

Neal, maybe you want to comment on that.

Mr. **Blake**. It is primarily for removing the ice from the aircraft, yes. It does provide some protection if applied at or near full strength for a period of time. Obviously, as precipitation continues to fall it does dilute the effectiveness. A part of our program is to look at concentration versus various levels of precipitation to define what the appropriate use of that material would be.

Mr. **Glickman**. But to the best of your knowledge there are no substitutes to glycol as a deicing agent? We have been using this for 30 years as the basic deicing solution?

Mr. **Blake**. That's correct.

Mr. **Glickman**. Is any of your work being done to try to find substitutes to glycol?

Dr. **Koenke**. I don't believe that that's included in the program at this point, but I could defer to Dick Adams, who is our technical expert in this area.

Dick, do we have any alternatives to ethylene glycol?

None known today.

Mr. **Glickman**. And again, there are no regulatory standards, to the best of your knowledge—realizing you are not in the regulation area—that would instruct the airlines on what mixtures to use or even when to use them?

Mr. **Albrecht**. I suspect that is right, Mr. Chairman. Now, whether there are company standards that we monitor or not I don't know.

Mr. **Glickman**. I personally just find that unbelievable in light of all the other areas of Federal regulatory efforts in aviation. This one just seems to have fallen through the cracks, but I suppose now that an accident occurred you will continue to enhance your research in this area.

I would like to pursue for a moment the area that was raised by Mr. Burnett on the issue of seats, crash survival and human tolerance. You had your viewgraphs about that. I will repeat what Mr. Burnett said:

> The FAA stands virtually alone in the safety research community with respect to its insistence that the human body, when restrained by only a seatbelt, cannot withstand significantly more intertial forces than those to which present passenger seats are designed.

I wonder if you would care to comment on that? I mean, by implication he is saying that you are fighting all the other scientific evidence in this area—and maybe you're not—and I think you deserve a chance to respond.

Dr. **Koenke**. I don't believe that we are fighting scientific evidence. I believe that we are looking for scientific evidence, and we have a program with the U.S. Army to try to determine the human tolerance levels. A lot of work has been done, and it is a very controversial issue, Mr. Chairman. A lot of the work that's been done has been done on young healthy males and is really not representative of the flying public. The seat design as the specs call for, 9-G's longitudinal, 4.5-G's downward, 2-G's upward, and 1.5-G's sideways.

The question that has to be looked at is, whether or not the human being can survive G levels at higher values than those designs. Now, I think it could be shown very easily that even for a very young healthy pilot, for example, if he is a 4-G environment for very long, not only will black out but will eventually die. It is a question of the length of time over which these G's must be sustained. Now we are doing work with the U.S. Army; we are also doing cadaver work; we are also doing work in preparation for monitoring the actual impulses that would be measured in the 720 crash test. So there is work going on; and, yes, it is a very controversial issue.

Mr. **Albrecht**. It is also a system problem, Mr. Chairman. You have to look at the human occupant, you have to look at the seat attachments to the floor as a total system. People say, "Gee, why don't you make the seats a lot stiffer?" Well, one product of that would be to pass heavier loads onto the human being sitting in the seat. So you certainly need to take care of things like seat attachments where it shouldn't come lose, but it is the system program we are looking at.

Mr. **Glickman**. One of the points I think is the implication of Mr. Burnett's testimony that this idea may be researched to death when in the meantime we could design some improvements in the crashworthiness of seats, and I think we have made our point. I assume that the crash of your Boeing 720 will take into account some of these things.

And you also indicated you were also going to install some seats in reverse position?

Mr. **Albrecht**. Let me check on that 1 second.

Yes, there will be reverse seats.

Mr. **Glickman**. Do you have any idea on the impact, what the impact of putting a seat in a reverse position would be in terms of the G force and the——

Dr. **Koenke**. I think it depends on the seat because, depending upon the structure of the seat, the back could collapse. You know, it depends upon how that seat is built.

Mr. **Glickman**. Do you know why the military has traditionally, in many cases, gone to a seat that faces to the rear?

Dr. **Koenke**. Probably because they feel that it is a safer way to go.

Mr. **Glickman**. It is curious, and I think it is something that shouldn't be neglected in your studies.

Are you also doing some work on why it seems, not always—and this is not a scientific fact—that passengers in the rear of an aircraft cabin, at least in large commercial aircraft crashes, seem to be more likely to survive than those located in the rest of an airplane?

Dr. **Koenke**. I am not sure that that is always true. It seems that there is some pattern there, but also over the wing area there is a large survivable population.

Mr. **Glickman**. I would like to go for a moment to a question that Mr. Burnett raised about cockpit recorders in airplanes that are not required to have them now.

The NTSB said that despite eight reiterations of recommendations to the FAA no satisfactory requirement has been introduced with respect to cockpit recorders. I wonder if that is because of the confusion in the state of research and development, or is it a regulatory decision?

Mr. **Albrecht**. Well, it is really not an R. & D. problem, Mr. Chairman. The companies are working small lightweight recorder; Westinghouse, for example, is doing this. It doesn't require an R. & D. expenditure, but the specification of a requirement is a regulatory action.

Mr. **Glickman**. Mr. Dunn.

Mr. **Dunn**. Thank you, Mr. Chairman.

You say it is not an R. & D. problem and, yet, Al, in the same breath you say that it is a weight problem. Doesn't that make it an R. & D. problem if it is too heavy for small aircraft?

Mr. **Albrecht**. Well, the recorders that Westinghouse and others are working on are very small and very lightweight. As you know, Mr. Dunn, current technology makes that a fairly easy thing to do.

So work is being done in the commercial market, and normally when that happens, unless there is some outstanding reason, we don't feel it makes sense to spend the taxpayers' money to do the same thing.

Mr. **Dunn**. Is there an outstanding reason in the cost?

Mr. **Albrecht**. I am sorry?

Mr. **Dunn**. Do you know what the cost involved for a small aircraft would be?

Mr. **Albrecht**. You won't like this answer. It is $7,000.

Mr. **Dunn**. You are right. I don't like it.

We have been talking about millions of dollars. Occasionally it occurs to me that there are simple solutions, and I go back to the testimony of Mr. Burnett when he was talking about the Eastern flight in Miami a number of years ago.

My understanding in reading through that transcript was that it basically was a result of the pilot being unaware that the autopilot had gone off, and that the solution was—and it is now on our aircraft—that we have, as someone said, another horn and whistle that even when we nudge that wheel the slightest, a bell goes off that tells us the autopilot is off. It is a relatively simple solution.

It occurs to me that there might be another simple solution for aircraft as to whether or not they are in a deiced condition at the moment that they roll onto the active runway. Rather than spend a million dollars of research on predicting icing conditions, I suggest that we station one observer at the point where the aircraft roll off the taxiway and onto the runway, given the fact that the pilots in the big aircraft virtually can't see their wings, let alone the body which none of us can see. Simply a thumbs up or a thumbs down from an observer as to whether that aircraft does or does not have ice on it would help solve this problem. Now, that doesn't require research dollars; that's one man out of a number of people that work at National for maybe a period of 5 hours a month at the most. Now why isn't that an effective, immediate, clearcut solution to the problem?

Mr. **Blake**. I think there are many things that one can do to address that problem.

Mr. **Dunn**. Let me rephrase that: What's wrong with my idea of an observer in a little tower there during periods of adverse weather that gives a thumbs up or thumbs down as to whether or not there is ice on your wings?

Mr. **Albrecht**. I'm not sure there is anything wrong with it, Mr. Dunn. It is not an R. & D. problem, as you point out, but we will pass it along.

Mr. **Dunn**. OK.

Last question, as it deals with—and you and I talked last week about the money not being spent—and Dr. Koenke has corrected me, there is some money being spent—testing of the runway itself and how you would improve those conditions rather than spend money on research as to how those conditions affect aircraft. I see a dramatic difference there. You came up with three different methods—heat tapes, steam air, and solar—and your best guess was about $10 million per runway.

Dr. **Koenke**. Correction. That wasn't the heat tape. I mean, it was an electrical way of heating the runway but not heat tape. The heat tape turns out to be much more expensive than either of those three alternatives.

Mr. DUNN. I guess my only reaction to that would be as a general contractor in the construction industry who has installed heat tapes, your $10 million figure sounds extremely high, like the old joke about an elephant being a mouse designed to government specs. I put it in as a general contractor, and I find difficulty believing your $10 million figure. It can be done far cheaper than that, and I think it is an alternative to the kind of solutions that we have been proposing.

I thank you.

Mr. GLICKMAN. Mr. Gore.

Mr. GORE. Thank you very much, Mr. Chairman.

As I believe you have noted for the record we had a markup of legislation scheduled in our full committee upstairs at the same time as this proceeding, and although it is unfortunate, but as the author of several amendments to that bill I had to present. I apologize to our witnesses.

I have a couple of questions for this panel. First of all, in the testimony of the National Transportation Safety Board, Mr. Burnett, he said, and I quote,

> The FAA stands virtually alone in the safety research community with respect to its insistence that the human body, when restrained by only a seat belt, cannot withstand significantly more intertial forces than those to which present passenger seats are designed.

Why does the FAA stand alone in the research community on this question?

Dr. KOENKE. Let me try it again.

The FAA is not alone. It is working with the U.S. Army and it has a program to determine what the human tolerance levels are that need to be sustained. And we are treating the human, the seat, the aircraft and the floor as a system in trying to determine what the parameters are that need to go into the design of that system. I don't think we are alone. I think that there is an honest difference of opinion.

Mr. GORE. Who else agrees with you?

Dr. KOENKE. The U.S. Army is working with us, sir.

Mr. GORE. Do they agree with your position on it.

Dr. KOENKE. Our position is that we are looking to determine what the number is that the human being can sustain.

Mr. GORE. Would you agree that nobody else in the commercial aviation area agrees with the FAA's position on this?

Dr. KOENKE. No. What I would say is that they are making assertions about the amount of G's that a human being can sustain, and what we are trying to do is to determine what the right number is and what the duration of the G level loading is. For example, if you take any human being, a healthy young pilot, put him in a 4-G environment for over a longer period of time, he will in fact black out and probably die after a certain period of time. The question is the duration of time over which the human being must survive these G levels. The shorter the duration the higher the G level that the human being can sustain. For example, in jogging, you know, the knee sustains very, very high G levels, but it is over a very, very short period of time.

Mr. **Gore**. Or, for example, a crash.

Dr. **Koenke**. A crash, it depends upon how the pulse is transmitted through the fuselage, through the floor, through the seat, and to the human being, and over what period of time that G loading must be sustained. That's the data we are looking for, sir.

Mr. **Gore**. I mean, but commonsense would—unless I am missing something here—seem to indicate that that's a pretty short period of time when a plane impacts.

Dr. **Koenke**. Short, relative to what? I mean, 100 microseconds.

Mr. **Gore**. Short, relative to 3 seconds.

Dr. **Koenke**. Yes, it is short relative to 3 seconds; yes, sir.

Mr. **Gore**. A lot of pilots have had the experience of blacking out from excessive G forces for a period of time, a couple of seconds, and then recovering in time to get their plane back under control. Correct?

Dr. **Koenke**. That's correct; yes, sir.

The question is, though, over what period of time and what level of G forces the human being, the flying public, can sustain. And I honestly believe that there is a very, very significant difference of opinion, honest technical difference of opinion.

Mr. **Gore**. Well, do you think that the current design of passenger seats is right around the range that is at the upper limit of what human beings can withstand?

Dr. **Koenke**. I would like to wait until the data is in, sir. I do not have an opinion as to whether it is right or wrong.

Mr. **Gore**. Well, I know that you covered some of this in your initial presentation, but in June of 1980 GAO said that you were waiting too long, and here it is almost spring of 1982. And I take it that you have said in your presentation you hope to come up with some answers soon, perhaps by this summer, is that correct?

Dr. **Koenke**. We will have some answers this summer, but we will not have difinitive answers until after the Boeing 720 crash test in 1984.

Mr. **Gore**. Well, so that the point is not—so you don't escape one of the central points of this hearing, we are trying to urge you to move faster, and I think that the overwhelming majority of the American people have precisely the same desire. And I would hope that you are a little bit uncomfortable with the pace thus far, and that in the wake of these hearings and the incidents which cause these hearings that you would move faster.

Mr. **Albrecht**. You could say we are uncomfortable, Mr. Gore.

Mr. **Gore**. All right.

Mr. **Glickman**. Would my colleague yield.

Mr. **Gore**. Certainly.

Mr. **Glickman**. Is there any reason other than budgetary why you couldn't speed up that Boeing 720 crash test?

Dr. **Koenke**. The work that we are doing with NASA requires the development of a remotely piloted equipment, and they are just starting that. You know, it is a joint program and it is a large program, and I don't see offhand, although we could take a look at it if you would like, but I don't see offhand.

Mr. **Gore**. Let me ask you about runway friction. Isn't it true that there is equipment currently available that the operators of Logan Airport would have used to determine the runway friction at the time of that incident, and that the FAA has just not required this even though it is currently available.

Dr. Koenke. There are current ways of measuring friction.

Mr. Gore. We have got one parked out front, incidentally.

Dr. Koenke. Sure, and there is more than one way to do it. The problem is that they don't correlate with each other for one thing. The other aspect of that question is bordering on regulatory issues and we are working in the R. & D. area and do not have control over the regulatory program.

Mr. Gore. Well, now, the Airline Pilots Association has already developed data that correlates the runway friction testers and the aircraft performance.

Dr. Koenke. That's not the correlation I am talking about, excuse me. The correlation I am talking about is between the MU meter, the Saab, and other runway friction measuring devices. They do not all correlate with each other to give the same measurement.

Mr. Gore. Well, Fahrenheit and centigrade thermometers don't correlate with each other, but you can——

Dr. Koenke. Yes, they do, sir. There is a formula that equates Fahrenheit to centigrade.

Mr. Gore. Well, that's right, if you have two different kinds of testers, if the data is different according to different weather conditions for each what is the problem with that?

Dr. Koenke. What I am saying is that given the same conditions they don't measure the same number, and you have a problem correlating one system measurement to another system measurement.

Mr. Gore. The MU meter and the Saab vehicle, I'm informed, were correlated last September.

Dr. Koenke. The MU and the Saab were but the other devices are not.

Mr. Gore. Well, if we have one that is correlated and that works, and that is correlated with aircraft performance, why don't we use it?

Dr. Koenke. That's a regulatory matter, sir. It is not a research matter.

Mr. Gore. Is there somebody on the panel that can speak to that? Why don't we use it if it is available? If Logan Airport had used that meter it could have provided data to the pilot of that aircraft telling him that he was going to slip off the end of the runway, but it is not required. Yet it is available. Why is that?

Mr. Albrecht. Mr. Gore, I really don't want to cop out on your question. It is a valid question. The point is we are not the people who are competent to answer that question. That really is an aviation safety issue. I just really don't know. However, we can pass it on and supply it for the record if you would like.

Mr. Gore. Well, we will pursue it in whatever proper form with those who do have responsibility for it.

Thank you very much, Mr. Chairman.

Mr. Glickman. Mr. Walker.

Mr. Walker. Thank you, Mr. Chairman.

Let me pursue the matter of the seat failures and your research on that.

As I understand it, you have testing under way on the seat standards. Now the problem is you are concerned about the G forces that the human body can survive. When, other than in an accident, do the G forces have anything to do with—I am talking about in commercial aviation now—have anything to do with the health and safety of the flying public?

Dr. KOENKE. Could you repeat that question, sir?

Mr. WALKER. When, other than in the middle of an accident would G forces come into play with regard to a passenger in commercial aviation?

Dr. KOENKE. I haven't got the slightest idea. I think that that's one that we are worried about, what the G level would be, yes.

Mr. WALKER. OK.

So in other words, we are talking about an accident situation now where you are concerned about G forces—the G forces do not effect passengers in any other instance in commercial aviation?

Dr. KOENKE. In an accident I would include an emergency landing, for example, with gear up. So that would be included in this discussion I would hope.

Mr. WALKER. OK, fine.

Now, is it your contention that there are people who would have survived air crashes that would not have survived had we had stiffer seats? Is that what you are investigating when you are taking a look at the G force problem that you are hung up on?

Dr. KOENKE. I don't think that I'm hung up on it. I think that the community is hung up on it.

Mr. WALKER. We are talking about FAA and the research you have been doing.

Dr. KOENKE. My concern is over the duration which the human being must sustain a G force. Over a very, very short, short infinitesimal period of time the human being can sustain extremely high G forces. Over longer periods of time the level of the G force comes down. The question that needs to be looked at and needs to be addressed is over what period of time does that impulse, the G impulse from a crash—what's that period of time and what does the human being subjected to.

Mr. WALKER. But the bottom line in that is that people who have been surviving airplane crashes would have died if you had stiffer seats? That is where the seats could withstand higher G forces.

Dr. KOENKE. It is quite possible that that is the case, yes.

Mr. WALKER. So in other words, your problem is that you believe that there are instances where if stiffer seats had been in the airplane people who presently survived the crash would have died?

Dr. KOENKE. It is a possibility.

Mr. WALKER. Well, how would you rate that possibility given the fact that we know from previous crashes, or at least NTSB has testified here today that there are people who have died as a result of the fact that the seats weren't stiffer?

Dr. KOENKE. That they were not stiffer?

Mr. WALKER. Yes.

We know that there have been a number of deaths attributed to that. How many would you say could be attributed to the other side?

Dr. **Koenke**. I don't know. We haven't had any crashes with stiffer seats.

Mr. **Walker**. Isn't that a legitimate question, though, to be asking given the fact that this kind of evidence has been around since at least the early 1960's? You know, you have evidence—FAA's internal research had clearly shown that seat failures had occurred in survivable aircraft crashes——

Dr. **Koenke**. That's true.

Mr. **Walker**. So we are talking about 20 years of records. Now it seems to me that at least you should be justifying why you are talking all this time to investigate the other side of the equation, that you claim that there would be some deaths that would result from those additional G forces.

Dr. **Koenke**. That's not my problem, sir. I think——

Mr. **Walker**. Then what is the problem? That's the only contention you have had for the reason why we should spending all of this time investigating the matter further.

Dr. **Koenke**. No, that's not accurate.

The point is the following: that there is a design specification right now for the seats and they are certified to that spec—9-G's longitudinal, 4.5-G's down, 2-G's up and 1.5-G's lateral. That's what the seats are tested against today. The question that we are looking at from a research point of view is what can the human being sustain? Is it a 14-G level longitudinal, for example, which would imply if that's the case then we might want to change the certification standard for the seat. Whether it is a stiff seat, or whatever kind of seat it is it is what the human being can take. We are looking at it from a systems point of view, not only just forward G's on the seat, but on the floor structure, the tiedown, the lap belt, and the human being.

Mr. **Walker**. I understand. I am using stiff seat generically here to talk about the whole problem of the fact that seats break loose in a crash. I am considering it generically here. I am not talking about just the design of a particular seat. But it still comes down to the fact that NTSB has recommmended to you that we do more, that your own internal research going back into the 1960's indicates that, and, yet, your testing is on a matter where we are not even sure at the present time that additional deaths would result even if you did go ahead.

Dr. **Koenke**. I am sorry. We are not worried about the additional deaths. We are looking at how we can save lives given the crash environment. We are not looking at the question of additional deaths that might occur due to a stiffer seat as you are implying.

Mr. **Walker**. OK, so are you telling me that essentially you are operating from the premise that indeed stronger standards are needed?

Mr. **Albrecht**. Mr. Walker, we are trying to establish an engineering——

Mr. **Walker**. No, was the answer no?

Dr. **Koenke**. No.

Mr. **Albrecht**. We are trying to establish an engineering data base against which you can make some decisions if the standards should be changed and not conjecture.

Mr. **Walker**. Aren't there accepted standards in the automobile industry with regard to G forces that human beings can withstand?

Mr. **Albrecht**. I'm sure there are.

Mr. **Walker**. Then why wouldn't those be adaptable to what we are doing in aircraft situations? Why all this additional research? If we know how much G force the human body can withstand based upon what we are doing in the automobile industry—the automobile has obviously come up with standards that are even stronger than aircraft—why would we continue this and why would we not take as a matter of premise on this that indeed we do need stronger seats when virtually everybody has recommended that except FAA?

Mr. **Albrecht**. I don't think you can take results from the automobile industry and apply them directly to the aircraft industry.

Mr. **Walker**. You can with regard to the G forces that the human being can withstand, can't you?

Mr. **Albrecht**. Not a bit. The human spine is a very stiff structure. The vertical forces are very important in an aircraft accident. I suspect it is a different scenario than you find in most automobile accidents.

Again, we are trying to establish an engineering basis against which to make decisions. That's what's taking the time.

Mr. **Walker**. And that's been going on for 20 years?

Mr. **Albrecht**. I can't defend 20 years. I can defend the last few.

Mr. **Walker**. The internal research at FAA goes back into the early 1960's.

Mr. **Albrecht**. Of course.

The regulation goes back at least that far. I am not sure we are getting anywhere, Mr. Walker. As you develop a data base you understand more about the problem, you establish regulations. Then the scenario changes, the type of aircraft change, the velocities change, and you have to change your data base, the knowledge against which you recommend regulations. It is a continuing process.

Mr. **Walker**. Are there any comparisons that exist between the survivability in military backward seating and the forward seating in commercial planes?

Mr. **Albrecht**. I don't know.

Again, the backward seat question has come up many times. That issue is an interface, again, between the regulating folks and the airlines industry. Recognize that most people don't like to fly backwards. They just plain don't like it. Now, that doesn't mean the FAA couldn't require them to, but that relation between industry and the flying public is not an engineering and development issue.

Mr. **Walker**. Most people don't like to wear the seatbelt either; however, we have convinced them over the years that wearing the seat belt is needed to help protect them in the event of a crash. If we also told them that sitting backward would help them survive a crash I think that probably they would accept that as a point, too. And it certainly is a question where you have the G forces spread throughout the entire body rather than on the belt alone in the backward seating. It seems to me that it is something that has some very direct applicability to the exact problem that we are talking about.

Mr. **Albrecht**. You may be right, Mr. Walker, but most rear seats in automobiles face forward.

Mr. **Walker**. Well, fine, but as I pointed out earlier, and it was agreed to, seats in automobiles also are built to a stiffer standard than what we have in the airline industry.

Mr. **Albrecht**. You still have lap belts, sir.

Mr. **Walker**. Thank you, Mr. Chairman.

Mr. **Glickman**. I would like to comment on two things. First, although I don't want to get into the subject of birds in detail today, I would like for you to provide for the committee an update of your research efforts on birds as a cause of engine failure or structural damage. I think that is a real sleeper issue that's going to develop more.

Second, I would like to comment that there are several members of the committee who are quite concerned that there is nobody here joining you today to talk either about airport operations or the regulatory side, to amplify what you are talking about today. We realize the policy is not within the jurisdiction, but we have some omissions—incompletions, for example, in the area that Mr. Gore raised on runway traction or friction, and things that you were not able to answer. That concerns us a little bit, and I think that it is something that we are going to pursue anyway, because it will relate directly to what recommendations that we make.

Mr. **Gore**. Will the gentleman yield?

Mr. **Glickman**. Yes.

Mr. **Gore**. I might say that we asked on three separate occasions that someone accompany you, that you have the proper people here to respond to those questions. Isn't that right?

Mr. **Albrecht**. No, Mr. Gore. I can read the letter we got which specifically said this was an R. & D.——

Mr. **Gore**. It wasn't in the letter. There were contacts between the committee staff and the liaison staff where this point was made specifically.

Mr. **Albrecht**. Mr. Gore, without pursuing it, my understanding is very clear and specific that the committee staffers understood the people who would be witnesses would be E. & D. personnel only. Now one basis for that was the fact that other hearings were taking place, simultaneous hearings, that occupied some of the people who might otherwise be here. But, nevertheless, I can certainly understand your concern and your desire to pursue this issue.

Mr. **Gore**. But we thought we had a clear understanding, and I hope that you will supply—get the proper people to supply the responses for the record to those questions.

Mr. **Albrecht**. Fine.

Mr. **Glickman**. We thank you for your testimony very much.

Our next witness is the panel composed of Dr. Jack Kerrebrock with NASA, Associate Administrator for Aeornautics and Space Technology; Mr. Raymond Siewert, Director of the Engineering and Technology Division, Department of Defense, who will be accompanied by Colonel Try, Director of Environmental and Life Sciences with the Defense Department, and Rear Adm. Stuart Nelson, Director of Safety Policy.

I might mention for the audience that it is our intention to go through lunch, to not recess, so as to be able to perhaps be out of here maybe by 2 or thereabouts; and that way we can expedite the hearings.

I think the idea is to have you together. Jack, of course, has been before this subcommittee on many different occasions, so it is always a pleasure having you here. Why don't you go ahead and begin. Your entire statement will appear in the record. So you may wish to summarize as you deem appropriate.

STATEMENT OF DR. JACK KERREBROCK, ASSOCIATE ADMINISTRATOR FOR AERONAUTICS AND SPACE TECHNOLOGY, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION; ACCOMPANIED BY BILL AIKEN, DIRECTOR, AERONAUTICS SYSTEMS DIVISION AND DICK TOBIASON

Dr. **Kerrerock**. Mr. Glickman, Mr. Gore, members of the subcommittees, I welcome the opportunity to appear before you today to discuss NASA's research on aviation safety. I have with me Bill Aiken who is Director of the Aeronautics Systems Division, and Dick Tobiason who is responsible for most of our FAA-related work.

As you are well aware, the safety record of the airlines is excellent. Prior to the Air Florida B-737 crash on departure from National Airport on January 13, 1982, the U.S. air carrier industry had experienced a 2-year period without a fatal accident. While serious accidents often motivate changes to increase safety, the preferred approach to maximizing aviation safety is by continual assessment of the overall system to detect safety problems before accidents occur, and the development of improvements where deficiencies are found.

NASA works closely with the FAA through FAA offices at the Ames Research Center and Langley Research Center, through local Headquarters contacts and the NASA-FAA Coordinating Committee.

I will briefly describe those NASA research efforts which cover: First, the human or aircrew safety factor; second, the aircraft; third, the air traffic control system; and, finally, hazardous weather conditions.

While the latter three factors have always been recognized, understanding the importance of the human factor in aviation safety is a more recent phenomenon. It wasn't until the 1970's that NASA formed a research division at our Ames Research Center to focus on aviation human factors and to place human factors in the role of an aeronautical discipline alongside the traditional disciplines of proplusion, aerodynamics, materials and structures, and guidance and controls.

Let me begin with a discussion of our work on human factors. I will briefly focus on several elements in the program.

The Aviation Safety Reporting System (ASRS) was developed subsequent to a fatal accident that occurred at Dulles Airport in December 1974. The accident resulted because the crew misunderstood an air traffic control clearance. A similar misunderstanding had occurred at the same place the previous month, which did not result in an accident but which was reported by the captain to his company. However, because there was no central collection and dissemination of such reports the incident did not serve to prevent the subsequent accident. The ASRS was created to fill this void. It is a voluntary, confidential, nonpunitive reporting system designed to surface deficiencies in the national aviation system before accidents occur. The ASRS, which is managed by NASA for the FAA, has received more than 30,000 reports since it was started April 19, 1976. It has issued 740 alert bulletins, published 24 technical reports and 32 safety newsletters, and responded to 316 special requests for safety data. The ASRS's proven ability to collect and analyze human error data has made it invaluable in the planning of future research programs in aviation safety. It is a constantly evolving system and it has contributed information to the Congress, FAA, the NTSB and all segments of the aviation community. ASRS has been used recently to assess the effects of the air controllers' strike. The President's Task Force on Aircraft Crew Complement also made use of the ASRS data in their report, particularly on the two/three person cockpit issue.

The second program I would like to discuss is circadian desynchronosis. It addresses the effects of fatigue and circadian desynchronosis, or jet lag, on aircrew performance. Some 75 percent of ASRS reports include problems in the transfer of information. The desynchronosis study at Ames is to determine if crewmembers are likely to make errors in transferring information when they are fatigued. To determine the extent and significance of the aircrew performance decrement, we have initiated a field study on a variety of trip sequences. This study will be followed by a series of full-mission simulation studies on crews, before and after extended flight duty periods, to isolate critical factors causing performance decrements and to identify and test ameliorative measures. NASA is presently compiling a comprehensive fatigue handbook for distribution to the aviation community. The military, as well as the civilian community, has shown interest in this work.

Automation has already made great strides in the cockpit as well as in the air traffic control system. The air carrier pilot is becoming less a controller of aircraft and more of a systems manager. There are potential human problems such as boredom, loss of skills, inattention, and difficulty in performing when a problem occurs. Automated systems perform far better than humans when working on dull, repetitious, precise manipulations, while humans are far more flexible in their ability to handle unforeseen events. Our research in this area is to develop a human engineering data base for automated systems and to develop methods of assessing the safety and reliability of integrated man/machine systems.

The next subject is Cockpit Display of Traffic Information (CDTI). We have a joint program with the FAA to investigate the potential advantages and limitations of the CDTI concept. With the advent of the FAA traffic alert and collision avoidance system the capability for sensing and displaying nearby traffic in the cockpit will be at hand. We are investigating the capability of such a display to aid pilots' situational awareness and their ability to assume some functions such as merging and spacing which are now accomplished via the air traffic control system and to allow the crew to react to problems which may occur in the highly automated air traffic control system of the future.

Another very important program in which we have worked closely with the FAA is called line oriented flight training, or LOFT. One of the primary means to assure aviation safety is training. In the LOFT program, we developed a set of guidelines that airlines could use in developing training programs making full use of the capability for realistic training offered by high fidelity simulators. The guidelines resulting from our study were incorporated into the FAA's 1981 Advisory Circular on LOFT.

The last portion of the human factors program I wish to discuss is the development of aircrew workload measures. It is important to understand the effect of display and control designs on pilot workload. Unfortunately, the state-of-the-art in workload measurement is far less than desired. We are making a concerted effort at Ames and at Langley to understand the factors which combine to form what humans experience as workload and then to develop measures of acceptable reliability for this quantity.

Next I would like to talk about fireworthy aircraft cabin interior materials. In direct support of the FAA's needs to improve occupant survivability in post-crash fires, the Ames Research Center and the Johnson Space Center will complete development of fireworthy seat cushions and fabrics in fiscal year 1982. These will eliminate the most abundant sources of flammable materials in the aircraft. Thus, they are important for breaking the fire chain and improving aircraft safety. The thin, lightweight fire-blocking layer concept utilizes protective fire resistant wrappings over contemporary polyurethane foam cushions to minimize flame spread, heat build-up and release of toxic gases. The most promising configurations will be tested in the Douglas Aircraft Co.'s cabin fire simulator starting tomorrow with industry witnessing these final tests. The Johnson Space Center/Solar Industries' development of fire resistant, lightweight and resilient polyimide foam seat cushions has been completed. These cushions are about one-half the weight of contemporary polyurethane cushions, and in full-scale tests in the FAA's C–133 fire simulator have yielded dramatic improvements in fire resistance in a postcrash fire scenario. We saw that this morning in the FAA video presentation. The foam manufacturer has advised us that production capabilities are being developed. Three airlines are evaluating these cushions in scheduled flights. Similar developments of lightweight, fireworthy interior ceiling, wall and floor panels are under way and will be continued. NASA will be providing these advanced materials to the FAA over the next several months for full-scale testing in the C–133 facility.

The British-developed AMK, or Antimisting Kerosene Safety Fuel, FM–9, as shown in laboratory and in full-scale FAA tests, has the ability to prevent major fires caused by ignition of a jet fuel mist cloud. This cloud develops when jet fuel is suddenly released from wing tank structures during a crash, and, in some accident scenarios, can be the dominant path for fire propagation from an ignition source to jet fuel spilled on the ground from ruptured tanks. The external fuel-fed fire then ignites the cabin materials.

In fiscal year 1982 the Lewis Research Center supported the FAA by completing evaluation of the compatibility of AMK fuel with the Pratt and Whitney JT-8D engine, the most common in-service engine. Engine components requiring modifications to accommodate AMK were identified.

A joint NASA/FAA/industry study of worldwide jet transport aircraft accident data was completed last year. The major conclusion derived from this effort was that crash fatalities resulted from either fire or trauma injuries in about equal proportions. This study was used to define crash conditions and situations for developing designs having improved crashworthiness. A NASA/FAA program that involves the full-scale crash testing of a B-720 aircraft in fiscal year 1984 is currently being planned. The results from the transport aircraft accident studies will be used to study the crash scenario for the full-scale crash test. Advanced crashworthy structures with emphasis on seat restraints will be evaluated. An analytical model of the B-720 transport under the prescribed crash scenario will be made for comparison and correlation with data from the planned crash test. The test will also evaluate the effectiveness of AMK.

Another area of research is crash behavior of composites. The results of this research will be compared to those for an all-metal fuselage section in order to assess material behavior and performance.

The scope of this work on aircraft icing and ice protection includes the basic of fixed-wing and rotary-wing aircraft ice accumulation under simulated and natural icing conditions. The final result will be the development of lightweight, low-power consumption, and, hopefully, low-cost ice protection systems. Essential to this end are many tasks such as analytical modeling, instrumentation, icing forecast improvements, pilot training, wind-tunnel testing in the unique Lewis 6-by-9 foot icing research tunnel and flight research to validate predictions of icing effects and protection system effectiveness. In fiscal year 1982 Lewis completed definition of civil and military icing research needs for general aviation, rotorcraft, commuter, and transport aircraft. Formal cooperative research programs were developed with the Army, Air Force, FAA, and the Governments of Canada and Great Britain. As one of its priority research needs, the FAA has requested from NASA specific icing research support in several areas, including data to upgrade its certification requirements, particularly for the rotorcraft. DOD makes extensive use of the icing research tunnel and of Lewis' expertise in evaluating engine inlet and ordnance ice protection systems.

Next let me discuss aircraft performance on runways. The relationship between the pilot, aircraft, and nonstandard runway conditions has been the subject of a long-term research program at Langley utilizing several unique facilities. These include the Aircraft Landing Dynamics Facility, several ground test vehicles, a ground handling simulator, and specially constructed runways at the Wallops Flight Facility. Research includes the evaluation of current transport antiskid braking systems on wet runways, development of advanced braking systems, and development of advanced tires to resist blowout and temperature buildup. Research continues on the prediction of aircraft stopping performance using ground vehicle measured friction data on wet and contaminated runways. These efforts were developed in close cooperation with the transport industry and the FAA. In fiscal year 1982 we will complete several important improvements to the ground handling simulator, evaluation of thermal effects on tire carcass strength, development of an analytical tire model, and reports on the performance of existing antiskid braking systems.

Langley continues to support the Air Force F-4 active control landing gear system. I should also point out that because of Langley's unique expertise and facilities, its engineers continually support the NTSB in accident investigations where unusual runway conditions are a factor, as for example, the Continental Airlines DC-10 runway overrun in Los Angeles. Ames has also assisted the NTSB by developing advanced analytical techniques for determining aircraft performance using data recorded by flight data recorders and air traffic control computers. Low level wind shears have been the cause of several major airline accidents. Ames is continuing low altitude flight research on an airborne wind shear detector using an infrared radiometer with a range of 3 to 5 miles. The preliminary results of this research show that it appears feasible to remotely sense shears associated with gust fronts. We plan further evaluation of this radiometer and measurement of the distribution of gusts across the wing span of a B-57B research aircraft in the NASA/FAA/NOAA/NCAR/NSF and University of Chicago joint airport weather studies. The acronym for that is JAWS. This research will be done at Denver's Stapleton Airport this summer.

Clear air turbulence, or CAT, research involves continued flight evaluations in the Ames C-141 aircraft, of a NASA/JPL-developed microwave radiometer to detect clear air turbulence. CAT conditions cannot be forecasted with the precision needed to guarantee avoidance. CAT encounters may result in passenger and crew injuries and, in extremely rare cases, aircraft damage and partial loss of control. A major safety research program at Langley involves flight research in the unique F-106 penetrator aircraft. Precise data are collected on direct lightning strikes, turbulence, winds, X-rays and atmospheric chemistry. The direct strike data is needed for design of new lightning protection concepts for future aircraft employing composite materials; advanced electronic displays; microprocessors; and digital flight and engine controls. By interagency agreement, this unique data is also being used by FAA and DOD to develop criteria for advanced technology aircraft. The wind and turbulence data collected by the F-106 is being used to further define wind shear data base, and is being correlated with similar data measured by the FAA/DOD/DOC advanced doppler weather radar (NEXRAD). Ames is continuing research on the use of head-up displays (HUD) in low visibility and wind shear conditions.

Next is wake vortex alleviation. Airport productivity could be improved dramatically by reducing the spacing between aircraft in the terminal airspace. NASA, in conjunction with the FAA, is investigating the means for alleviating and avoiding the wake vortices behind transport aircraft to safely provide for this reduced spacing. NASA's approach is to derive technology that will allow existing and future aircraft to be configured so that potentially dangerous wake vortex flows can be minimized, whereas the FAA's efforts are in wake detection and avoidance.

On the subject of aircraft use versus design, Langley is continuing analyses of data recorded by modern transport aircraft digital flight data recorders to develop a data base on the usage of aircraft and systems relative to original design criteria. The digital data are used to define actual aircraft operating conditions and the problems requiring research. An example is data on tire speeds and antiskid system performance from an in-service L-1011.

The FAA requirements for use of advanced simulators should provide improvements in aircrew performance under normal and emergency conditions, including many of the weather hazards previously discussed. NASA research data can be used by the FAA and airlines in advanced simulators. Some matters which can be addressed include aspects of human factors, aircraft performance on various runway surface conditions, atmospheric turbulence, wind shear, airframe icing and heavy precipitation. The use of these meteorology research products in advanced simulators was the theme of last year's NASA/FAA/NOAA meteorology workshop with industry.

Finally, Mr. Chairman, I would like say a little about our general aviation safety research programs. NASA's general aviation and commuter aircraft research emphasizes improvements in safety, with major efforts directed toward improving aircraft stall/spin characteristics, structural design for improved occupant crash survivability, and improvements in single pilot effectiveness under instrumented flight rules. Research in the stall/spin area has concentrated primarily on the development of an experimental data base using models and full-scale aircraft. Additional emphasis is being placed on the development of analytical techniques for predicting aircraft stall/spin characteristics and establishing reliable design methods.

Our crash-dynamics program is a joint NASA/FAA program to provide aircraft structural design technology for increasing passenger survivability in the event of a crash. Computer programs developed by NASA which predict aircraft structural response during an airplane crash will be released this year to industry. Dynamic testing of load-limiting aircraft seats and fuselage structures is also continuing with emphasis on unique subfloor concepts. This effort will be extended into the realm of composite materials.

In connection with single-pilot IFR, the "follow-me box" or FMB concept which uses a computer-generated cockpit display to provide a target for the pilot analogous to VFR operation is being studied to optimize parameters. Investigations will determine the feasibility of using synthetic voice technology to reduce pilot workload. A cooperative effort with the FAA will be initiated to investigate software requirements for transmitting real-time weather data from ground-based radar, combined with aircraft position, for cockpit display. A more comprehensive discussion of NASA's safety-related research has been submitted in my statement for the record.

In closing, let me note that NASA aviation safety research is an integral part of NASA's overall aeronautics research program and, as such, reflects our efforts to improve the performance, speed, safety, and efficiency of aeronautical vehicles. We work closely with the FAA, NTSB, airlines, and other user groups and manufacturers through advisory committees and workshops to determine research opportunities and to disseminate results. We will continue to explore new avenues to improve safety for the air transportation system.

This concludes my discussion of NASA's aviation safety research. I would like to thank both subcommittees for their continued interest in this vital area.

[The prepared statement of Dr. Kerrebrock follows:]

HOLD FOR RELEASE UNTIL
PRESENTATION BY WITNESS
MARCH 9, 1982

Statement

of

Dr. Jack L. Kerrebrock
Associate Administrator for
Aeronautics and Space Technology

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the

Subcommittee on Investigations and Oversight
and the
Subcommittee on Transportation, Aviation and Materials
Committee on Science and Technology
House of Representatives

Mr. Chairmen and Members of the Subcommittees:

I welcome the opportunity to appear before you today to discuss NASA's research on aviation safety. As you are well aware, the safety record of the airlines is excellent. Prior to the Air Florida B-737 crash on departure from National Airport on January 13, 1982, the United States air carrier industry had experienced a two-year period without a fatal accident. Recent accidents have brought a great deal of media attention to aviation safety, especially to the winter hazards of ice and snow and to crashworthiness. While serious accidents often motivate changes to increase safety, the preferred approach to maximizing aviation safety is to continually assess the overall system to detect safety problems before accidents occur, and develop improvements where deficiences are found.

Concerns for aviation safety should not be limited to the air carriers, whose safety record exceeds that of other segments of the aviation community. It is necessary to include general aviation, helicopters, air-taxis, and commuters as well.

As I stated in our February 17 FY 1983 aeronautics testimony, safety research utilizing NASA's unique facilities and expertise in aeronautics is conducted in cooperation with the FAA. I will now briefly describe those NASA research efforts which cover the human or aircrew, the aircraft, the ATC system and hazardous weather conditions. While the latter factors have always been recognized, understanding of the importance of the human factor in aviation safety is a more recent phenomenon. It wasn't until the 1970's that NASA formed a research division at the Ames Research Center to focus on aviation human factors, and place human factors in the role of an aeronautical discipline alongside the "traditional" disciplines of propulsion, aerodynamics, materials and structures, and guidance and controls.

Human Factors

I will discuss the following elements in the Human Factors program: the Aviation Safety Reporting System, circadian desynchronosis, advanced automation, Cockpit Display of Traffic Information, simulation technology, and workload measurement.

Aviation Safety Reporting System (ASRS) - The ASRS was developed subsequent to a fatal accident that occurred at Dulles in December 1974. The accident resulted because the crew misunderstood an ATC clearance. A similar misunderstanding had occurred at the same place the previous month which did not result in an accident but which was reported by the captain to his company. However, because there was no central collection and dissemination of such reports, the incident did not serve to prevent the subsequent accident. The ASRS was created to fill this void. It is a voluntary, confidential, non-punitive reporting system designed to surface deficiencies and discrepancies in the National Aviation System before accidents occur. The ASRS, which is managed by NASA for the FAA, has received more than 30,000 reports since it was started on April 19, 1976. ASRS has issued 740 alert bulletins, published 24 technical reports and 32 safety newsletters, and responded to 316 special requests for safety data. The technical reports covered such items as: runway incursions, cockpit distractions, interpersonal communication problems, the limitations of the air traffic control system in conflict avoidance, and potential conflict at uncontrolled airports. The "cockpit distractions" report was instrumental in the FAA's implementation of regulations requiring a "sterile" cockpit below 10,000 feet, where the flight crew is isolated from nonflight-oriented events.

The ASRS's proven ability to collect and analyze human error data makes it invaluable in the planning of future research programs in aviation safety. It is a constantly evolving system and has contributed information to the Congress, FAA, NTSB and all segments of the aviation community. ASRS was recently used to assess the effects of the air controllers' strike. The President's Task Force on Aircraft Crew Complement made use of the ASRS data in their report.

Desynchronosis - The second program I will discuss is directed toward identifying the effects of fatigue and circadian desynchronosis (i.e., jet lag) on aircrew performance. Seventy-five percent of ASRS reports include problems in the transfer of information. The objective of the desynchronosis study at Ames is to determine if crew members are likely to make errors in transferring information when they are fatigued. To determine the extent and significance of the aircrew performance decrement, a field study on a variety of trip sequences was initiated. This study will be followed by a series of full-mission simulation studies of crews, before and after extended flight duty periods, to isolate critical factors causing performance decrements and to identify and test ameliorative measures. NASA is presently compiling a comprehensive fatigue handbook for distribution to the aviation community. The military, as well as the civilian community, has shown interest in this work. The Air Force and the Army have sent full-time personnel to Ames to participate in the research program. The Air Force Military Airlift Command is preparing to run a parallel fatigue and desynchronosis study on their aircrews.

Automation - The FAA Administrator recently said that his number one problem is dealing with the growth of aircraft operations, expected to rise from 100,000 aircraft flying each day now to 200,000 in the next nine years. To deal with this projected level of air traffic, the FAA can either hire thousands of controllers or automate, and has chosen the latter. Automation has already made great strides in the cockpit as well as in the air traffic control system. The air carrier pilot is becoming less a controller of aircraft and more of a systems manager. There are potential human problems, such as boredom, loss of skills, inattention, and difficulty in performing when a problem occurs. Automated systems perform far better than humans at dull, repetitious, precise manipulations, while humans are far more flexible in their ability to handle unforeseen events. The objective of the NASA research in this area is to develop a human engineering data base for automated systems, and to develop methods of assessing the safety and reliability of integrated man-machine systems. Our ability to determine the reliability of hardware and software systems is far more advanced than that which is needed to determine the reliability of the "human subsystem." Initial studies will address the automation of alerting and warning systems, human monitoring of complex systems, and the effects of transition to increasingly automated systems on crew personnel.

Cockpit Display of Traffic Information (CDTI) - NASA has a joint program with the FAA to investigate the potential advantages and limitations of the CDTI concept. With the advent of the FAA Traffic Alert and Collision Avoidance System, the capability for sensing and displaying nearby traffic in the cockpit will be at hand. NASA is investigating the capability of such a display to aid pilots' situational awareness and their ability to assume some functions such as merging and spacing which are now accomplished via air traffic control, and to allow the crew to react to problems which may occur in the highly automated air traffic control system of the future. The potential problems that such a display might create, such as unilateral pilot actions are also being investigated.

Simulation Technology - Another very important program in which NASA has worked closely with the FAA is called Line Oriented Flight Training (LOFT). One of the primary means to assure aviation safety is training. In the LOFT program, we developed a set of guidelines that airlines could use in developing training programs making full use of the capability for realistic training offered by today's high fidelity simulators. The guidelines resulting from the NASA study were incorporated into the FAA's 1981 Advisory Circular on LOFT.

Workload Measurement - The last element of the human factors program I wish to discuss is the development of aircrew workload measures. It is important to understand the effect of display and control designs on pilot workload. Unfortunately, the state-of-the-art in workload measurement is far less than desired. NASA is making a concerted effort, both at Ames and at Langley, to understand the factors which combine to form what humans experience as "workload" and then to develop measures of acceptable reliability.

A related human factors program at Ames includes the investigation of helicopter displays and controls which will allow the pilot to perform missions with reduced workload and improved safety. The objectives are to explore experimentally the utility of advanced visual displays, synthetic voice, continuous auditory displays, and integrated controls.

That concludes my discussion of NASA's human factors research which is related to safety. Now I will briefly discuss our research dealing with the aircraft itself and hazardous meteorology.

Fireworthy Aircraft Cabin Interior Materials

In direct support of the FAA's needs to improve occupant survivability in post-crash fires, Ames and the Johnson Space Center will complete development of fireworthy seat cushions and fabrics in FY 1982. These will eliminate the most abundant sources of flammable materials in the aircraft. Thus, they are important for breaking the fire chain and improving aircraft safety. The thin, lightweight fire-blocking layer concept utilizes protective fire resistant wrappings over contemporary polyurethane foam cushions to minimize flame spread, heat build-up and release of toxic gases. The most promising configurations will soon be in large-scale testing in the Douglas Aircraft Company's Cabin Fire Simulator. Detailed fire resistance measurements will be taken in this simulator and related to earlier small-scale tests and full-scale tests. The Johnson Space Center/Solar Industries development of fire resistant, lightweight and resilient polyimide foam seat cushions has been completed. These cushions are about one-half the weight of contemporary polyurethane cushions and, in full-scale tests in the FAA's C-133 fire simulator, have yielded dramatic improvements in fire resistance in a post-crash fire scenario. Three airlines are currently evaluating these polyimide foam cushions in service. The foam manufacturer has advised us that production capabilities are being developed.

Similar developments of lightweight fireworthy interior ceiling, wall and floor panels are underway and will be continued. NASA will be providing these advanced materials to the FAA over the next several months for full-scale testing in the C-133 facility. In FAA tests, Ames-developed fire resistant cabin windows have shown fire penetration resistance equal to the resistance of the fuselage itself. Further research in lightweight interior panels using graphite fibers and resins which do not produce toxic gases will be conducted in FY 1983. Supporting research includes fire and survivability modeling and fire extinguishing chemicals.

Anti-Misting Kerosene Safety Jet Fuels (AMK)

The British-developed AMK safety fuel, FM-9, has shown, in laboratory and in full-scale FAA tests, the ability to prevent major fires caused by ignition of a jet fuel mist cloud. The cloud develops when jet fuel is suddenly released from wing tank structures during a crash. In some accident scenarios it can be the dominant path for fire propagation from an ignition source to jet fuel spilled on the ground from ruptured tanks. The external fuel-fed fire then ignites the cabin materials. In FY 1982, Lewis Research Center supported the FAA by completing evaluation of the compatibility of AMK fuel with the Pratt and Whitney JT-8D engine, the most common in-service engine. Engine components requiring modifications to accommodate AMK were identified. Ames and JPL are supporting the FAA with the laboratory evaluations of AMK fuels behavior.

Transport Aircraft Crashworthiness

The emphasis in the aircraft crashworthiness program is being shifted from general aviation to transport aircraft. A joint NASA/FAA/industry study of jet transport aircraft accident data was completed last year. A major conclusion derived from this effort was that crash fatalities resulted from either fire or trauma injuries in about equal proportions. This study was conducted to define crash conditions and situations for developing designs having improved crashworthiness.

A NASA/FAA program that involves the full-scale crash testing of a B-720 aircraft in FY 1984 is currently being planned. The results from the transport aircraft accident studies will be used to establish the crash scenario for the full-scale crash test. The design of onboard instrumentation and data systems to measure and record the structural response of the B-720 during the crash test is currently under study. Advanced crash-worthy structures with emphasis on seat restraints will be evaluated. Prior to this test, an analytical model of the B-720 transport under the prescribed crash scenario will be made for comparison and correlation with data from the planned crash test. The test will also evaluate the effectiveness of AMK.

Another area of research is crash behavior of composites. A Langley study with Lockheed is underway to characterize the behavior of basic composites for structural components under tearing, crushing compression loadings and wear due to abrasion. A Phase II study in FY 1983 will evaluate the crashdynamics of composite transport aircraft sub-flooring. The results of the study will be compared to those for an all-metal fuselage section in order to assess material behavior and performance.

Aircraft Icing and Ice Protection

A resurgence in icing research began at Lewis in 1978 after more than 20 years of inactivity. Increased all-weather operating requirements, both civil and military, brought on by advances in aircraft avionic systems and expanded mission requirements motivated the resurgence. The scope of the research includes the basics of fixed wing and rotary wing aircraft ice accumulation under simulated and natural icing conditions. The final result will be the development of lightweight, low-power consumption and, hopefully, low-cost ice protection systems. Essential to this end are many tasks such as analytical modeling, instrumentation, icing forecast improvements, pilot training, wind-tunnel testing in the unique Lewis 6x9-foot Icing Research Tunnel (IRT), and flight research to validate predictions of icing effects and protection system effectiveness. The IRT is the most heavily scheduled wind tunnel at Lewis. In FY 1982, Lewis completed extensive definition of civil and military aviation icing research needs for general aviation aircraft, rotorcraft, commuters and transports. An expanded long-term research program was initiated and formal cooperative research programs were developed with the Army, Air Force, FAA and the governments of Canada and Great Britain. Supporting research through industry contracts and university grants continues. A flight research program was started using a deHaviland Twin Otter to correlate icing instrumentation performance measured in the icing tunnel with actual conditions encountered in flight. As one of its priority research needs, the FAA has requested from NASA specific icing research support in several areas, including data to upgrade its certification requirements, particularly for rotorcraft. Also in FY 1982, Lewis initiated research in the IRT on ice protection systems for airfoil leading edges, using an electro-impulse concept. This technology has the potential for dramatic weight and power savings over contemporary systems. DOD makes extensive use of the IRT and of Lewis expertise in evaluating engine inlet and ordnance ice protection systems.

Aircraft Performance on Runways

The relationship between the pilot, aircraft and non-standard runway conditions has been the subject of a long-term research program at Langley utilizing several unique facilities. These include the Landing Loads Track, several ground test vehicles, a ground handling simulator and specially constructed runways at the Wallops Facility. Research includes the evaluation of current transport anti-skid braking systems on wet runways, development of advanced braking systems, and development of advanced tires to resist blowout and temperature buildup. The correlation of effective braking coefficients of friction measured by ground vehicles and instrumented aircraft is an ongoing research program. In FY 1982, research began on the effects of tire and wheel failures on loads transmitted to the aircraft and the ability of pilots to control the aircraft on various runway surfaces. This effort was developed in close cooperation with the transport industry and the FAA. In FY 1982, we will complete several important improvements to the ground handling simulator, evaluation of thermal effects on tire carcass strength, development of an analytical tire model, and reports on the performance of existing anti-skid braking systems. Langley continues to support the Air Force F-4 active control landing gear system. In FY 1983, Langley will begin extensive modifications to upgrade and extend the Landing Loads Track speed and weight capabilities to match current and future transport aircraft. FY 1983 should also see completion of the research on the effects of blown tires and failed wheels on aircraft performance. I should also point out that because of Langley's unique expertise and facilities, its engineers continually support the NTSB in accident investigations where unusual runway conditions are a factor, as for example, the Continental Airlines DC-10 runway overrun at Los Angeles. Ames has also assisted the NTSB by developing advanced analytical techniques for determining aircraft performance using data recorded by flight data recorders and ATC computers.

Wind Shear, Turbulence and Storm Hazards

Low level wind shears have been the cause of several major airline accidents. Extensive research and development to forecast and detect shears from both the ground and the cockpit have been under way for several years.

Ames is continuing low altitude flight research on an airborne wind shear detector using an infrared radiometer with a range of 3 to 5 miles. The preliminary results of this research show that it appears feasible to remotely sense shears associated with gust fronts. We plan further evaluation of the radiometer in the NASA, FAA, NOAA, NCAR, NSF, and University of Chicago Joint Airport Weather Studies (JAWS) research at Denver's Stapleton Airport this summer. The JAWS program is vital to the accurate real-time characterization of severe wind shears associated with thunderstorm microbursts, simulation of aircraft performance and evaluation of wind shear detectors, warning and dissemination systems. As part of the NASA structures research effort, the Langley B-57B research aircraft will participate in the JAWS research to measure the distribution of gusts across its wing span.

Clear Air Turbulence (CAT) research involves continued flight evaluations in the Ames C-141 aircraft of a NASA/JPL-developed microwave radiometer to detect CAT. CAT conditions cannot be forecast with the precision needed to guarantee avoidance. CAT encounters may result in passenger and crew injuries and, in extremely rare cases, aircraft damage and partial loss of control.

A major safety research program at Langley involves flight research in the unique F-106 storm penetrator aircraft. This specially protected and instrumented aircraft penetrates thunderstorms at high altitudes to collect detailed and precise measurements of direct lightning strikes to the aircraft. Data are also collected on turbulence, winds, x-rays and atmosphere chemistry. In order to conduct this research safely and to have confidence in getting direct strikes, Langley has developed advanced meteorology forecasting techniques which may evolve into routine operational tools in the future. During the last two years, twenty direct lightning strikes were recorded by the F-106 during the spring and summer sessions. NASA is planning to increase the sample size by several times this fiscal year. The direct strike data is needed for design of new lightning protection concepts for future aircraft employing composite materials, advanced electronic displays, microprocessors and digital flight and engine controls. By interagency agreement, this unique data is also being used by FAA and DOD to develop criteria for advanced technology aircraft. The wind and turbulence data collected by the F-106 is being used to further define a wind shear data base and is being correlated with similar data measured by the FAA/DOD/DOC advanced doppler weather radar. Ames is continuing research on the use of Head-Up Displays in low visibility and wind shear conditions.

Another meteorological hazard is heavy rainfall with and without wind shear. Tasks within this Langley program include the effects of water films caused by heavy rains on airborne weather radome and overall aircraft performance. The precipitation research is conducted in Langley wind tunnels and on the F-106 aircraft.

Wake Vortex Alleviation

Airport productivity can be improved dramatically by reducing the spacing between aircraft in the terminal airspace. NASA, in conjunction with the FAA, is investigating means for alleviating and avoiding the wake vortices behind transport aircraft to safely reduce the spacing. NASA's approach is to derive technology that will allow existing and future aircraft to be configured so that potentially dangerous wake vortex flows can be minimized, whereas the FAA's efforts emphasize wake detection and avoidance.

Ozone

An example of quick response research includes the analyses of NASA's NIMBUS-7 satellite-measured ozone data. A cooperative NASA/FAA/airline program is determining the relationships between the ozone data, turbulence, jet stream location, height of the tropopause and the ozone concentrations at cruise altitudes near the tropopause.

Aircraft Use vs. Design

Langley is continuing to analyze data recorded by modern transport aircraft digital flight data recorders to develop a data base on the usage of aircraft and systems relative to original design. This program is an expansion of a similar general aviation program now completed, which used analog recorders on a wide variety of aircraft. The digital data are used to define actual aircraft operating conditions and problems requiring research. An example is data on tire speeds and anti-skid system performance collected from an L-1011.

Advanced Flight Training Simulators

The FAA requirements for use of advanced simulators should provide improvements in aircrew performance under normal and emergency conditions, including many of the weather hazards previously discussed. NASA research data can be used by the FAA and airlines in advanced simulators. Some matters which can be addressed include aspects of human factors, aircraft performance on various runway surface conditions, atmospheric turbulence, wind shear, airframe icing and heavy precipitation. These latter topics were the theme of last year's NASA/FAA/NOAA sponsored meterology workshop. This annual workshop has been an important means to define military and civil aviation research needs as well as disseminate results.

General Aviation Safety Research Programs

NASA's general aviation and commuter aircraft research emphasizes improvements in safety with major efforts directed toward improving aircraft stall/spin characteristics, structural design for improved occupant crash survivability, and improvements in single pilot effectiveness under instrument flight rules.

Stall/Spin - Up to this time, research in the stall/spin area has concentrated primarily on the development of an experimental data base using models and full-scale aircraft. During FY 1982, additional emphasis is being placed on the development of analytical techniques for predicting aircraft stall/spin characteristics and establishing reliable design methods. Concentration on the development of these analytical prediction methods, aided by the extensive experimental data base accumulated in past years, will continue in FY 1983. While not a joint program with the FAA, the program is conducted with their full understanding and endorsement.

Crash Dynamics - This is a joint NASA/FAA program to provide aircraft structural design technology for increasing passenger survivability in the event of a crash. During FY 1982, computer programs developed by NASA, which predict aircraft structural response during an airplane crash, will be released to industry. Dynamic testing of load-limiting aircraft seats and fuselage structures is also continuing with emphasis on unique subfloor concepts embodying the best features of previous research. Evaluation of design methods for optimal crash load-limiting structures will continue in FY 1983, extending this effort into the realm of composite materials.

Single Pilot IFR - During FY 1982, the "follow-me box" (FMB) concept, which uses a computer-generated cockpit display to provide a target for the pilot analogous to VFR operation, will be studied to optimize parameters. Investigations will determine the feasibility of using synthetic voice technology to reduce pilot workload. A cooperative effort with the FAA will be initiated to investigate software requirements for transmitting real-time weather data from ground-based radar, combined with aircraft position, for cockpit display. In FY 1983, flight tests of an optimized FMB concept and a refined Automated Terminal Approach System, a system for automating pilot functions during instrument runway approaches and holding patterns, will be conducted.

CONCLUSION

In closing, NASA aviation safety research is an integral part of NASA's overall aeronautics research program and as such reflects our efforts to improve the performance, speed, safety and efficiency of aeronautical vehicles. We work closely with the FAA, NTSB, airlines and other user groups, and manufacturers through formal advisory committees to determine research opportunities and to disseminate results. We will continue to explore new avenues to improved safety for the air transportation system.

This concludes my discussion of NASA's aviation safety research. I would like to thank both Subcommittees for their continued interest in this vital area.

STATEMENT OF RAYMOND SIEWERT, DIRECTOR, ENGINEERING AND TECHNOLOGY, DEPARTMENT OF DEFENSE, ACCOMPANIED BY COL. PAUL TRY, DIRECTOR, ENVIRONMENTAL AND LIFE SCIENCES; AND COLONEL WILDER, ASSISTANT DIRECTOR, FOR SAFETY POLICY

Mr. **Siewert**. Mr. Chairman, because of the broad range of technology associated with the subject here today, we are accompanied by several technical experts from the military services to assist in answering your questions.

I will briefly discuss our aviation safety program, the way that we apply lessons learned from mishap and discrepancy reports, some of our safety-related research and development projects in new applications of available technology, and finally suggest some areas where we feel that additional research and development are indicated.

Military aviation accidents are, of course, a matter of very real continuing concern to the Department of Defense. Military aviation, particularly tactical aviation, constitutes a most demanding operational environment. Military aircraft and associated operational systems are designed on the cutting edge of available technology and built to meet complex, exacting requirements of modern air warfare. Aircrews and ground support personnel train rigorously in peacetime to make maximum effective use of aviation system capabilities when and if they are required to do so in combat. This means that our aircraft are operated out to the limits of their performance envelopes. Within those constraints, however, aviation safety is a paramount consideration and an inseparable aspect of operational readiness.

By concerted action over the past 25 years, the military departments have achieved a twelvefold reduction in aircraft accident rates. And 1981 was one of the best years ever for military aviation safety.

This remarkable long-range achievement has been the product of lessons learned from increasingly sophisticated investigation and analysis of accidents, and resultant, sweeping improvements in aircrew and maintenance training, flight discipline, logistic support, research and development, and the application of advanced technology in aircraft design and reliability. In very recent years, the rate of improvement has slowed, as the more obvious problems have been solved. Substantial further improvement will require innovative approaches and special efforts, which are the current service priorities.

We devote extensive effort to identify and eliminate or control aviation hazards related to aircraft, operational facilities, human factors, and the interfaces between all three. These efforts include structured hazard analysis and correction at all stages in the system acquisition process; the analysis of data and corrective actions derived fom investigations of accidents, near accidents, and material deficiency trends; and research, development, and application of advanced technology.

I will now discuss some of the safety-related research and technology activities that we have underway, beginning with our work relating to aircraft crashworthiness.

Within DOD, the Army has been the lead service for conducting crashworthy aircraft research and development and developing subsequent aircraft design data. Recognizing that approximately 90 percent of all accidents involving helicopters were potentially survivable, and that the relatively low weights and speeds of helicopters made them attractive candidates for crashworthy designs, the Army initiated a program in 1959 to develop the required technology.

The essence of crashworthiness is to employ a number of components, such as landing gear, crushable belly structure, crew restraints, cargo restraints, and energy-absorbing seats, all functioning as a system which uses all of the available stopping distance to bring about a controlled deceleration of aircraft occupants. The system is designed to perform this role so that deceleration loads are within human tolerance, without injury, for 95 percent of the accidents.

The proof of the pudding, as it were, of these various energy-absorbing features for helicopters is our full-scale crash test. These tests are not only invaluable for obtaining impact dynamics and structural deformation data but also for validating mathematical models of the system which are required if we are to optimize crashworthiness features in new aircraft. Of the 41 tests performed to date, the last 3 have had their structures mathematically modeled. In July 1981, we conducted a crash test for the YAH-63 attack helicopter. This test was extremely useful in evaluating approximately 10 Army/Navy/NASA-developed crashworthy improvements that may find both military and civil applications. Our current efforts are devoted toward tests of structures made of the newer materials, such as organic composites. The Army has tested full-scale fuselage sections, constructed of a lightweight composite, and plans to conduct full-scale crash tests of complete helicopter airframes made of composite materials in 1984.

I would like to discuss some of our efforts in fire protection research. Emphasis in military aircraft fire protection is directed toward the enhancement of inflight combat survivability and the resolution of selected operational fire mishap problems. Although the aircraft cabin fire hazard is an area of concern, longstanding, comprehensive, and impressive NASA and FAA programs related to cabin materials, fire propagation, and related human survivability aspects have been addressing the pertinent issues. We monitor this work closely and incorporate the applicable findings into the design requirements for new aircraft.

With regard to fuel flammability, we are aware that the FAA and NASA currently are conducting an extensive program to develop the engineering data necessary for the introduction of antimisting fuel into service use. Although the military services are not now presently performing any research in this area, we are monitoring the FAA program for possible application to the military air fleet.

We have been investigating the use of intert atmospheres in fuel tank voids to prevent explosions. The C5-A aircraft uses a liquid nitrogen fuel tank interting system which to date has been credited with saving one C-5 aircraft. An onboard inert gas generator system currently under development by the Air Force will provide the same level of protection but would significantly lower logistics and weight penalties. Extensive full-scale ground tests of two competing systems will be conducted in 1982 and 1983. Flight tests, of the preferred system, are planned for 1984.

The Army has experienced a dramatic reduction in the number of helicopter crash fatalities since the development and incorporation of the crashworthy fuel system. In this concept, the old bladder fuel cells are replaced with nylon laminate fuel tanks, which meet crashworthy criteria established by the Army. After incorporation of the crashworthy fuel system, beginning in 1970, there have been no thermal fatalities resulting from the failure of this system.

In a related effort, the Air Force is pursuing the development of nonflammable hydraulic fluid to replace the current petroleum base fluid. We have identified and tested an excellent candidate. Work is currently underway to improve the fluid lubricity, antiwear, and viscosity properties, develop compatible seals, and determine the component system and design changes required to incorporate this fluid into new aircraft. We are projecting this technology will be available for use in new aircraft systems by 1987.

I would now like to briefly discuss our activities in aircraft control on the ground, including work to improve tire traction. The Air Force has initiated development of an automatic control system, to relieve much or all of the pilot workload at high speeds and adverse conditions. This system would work on the ground, much like the flight control system of modern fighters like the F-16 works in the air. This system controls the steering, braking, rudder of the aircraft to maintain directional control, lateral, position, and break the aircraft to a safe stop. Feasibility studies of the concept have been demonstrated, using computer simulations of the F-4 program.

The next phase of the program will be to evaluate the automatic system performance in comparision with human pilots through manned simulation. The Air Force is developing an Aramid fiber radial tire, which promises increased traction and cornering capabilities, as well as reduced tire weight and increased reliability. Aramid cord has the essential properties needed for radial aircraft tire construction. This program is planned to include fabrication of laboratory tests of a fighter-sized radial aircraft tire and identify the refinements required to produce a fully qualified flightworthy tire.

Siping is another way of improving tire traction. In this concept, developed by Marcy Inc., very small slits are cut into the tread surface of the tire. Laboratory and track tests of siped tires are currently being conducted by the Air Force, Navy, and the FAA. Results to date have shown significant improvements in wet surface traction, without compromising high speed tread integrity.

Like all operators of large numbers of aircraft, DOD is concerned about environmental and natural hazards to flight safety. Much of our research has been and continues to be focused on identification of the nature of the hazards, effects on the aircraft, and developing methods of aircraft protection. For example, our initial work related to the problem of wind shear focused on developing mathematical models of the phenomenon. In 1977, four critical combinations in changes of wind speed and direction with altitude were identified. Based on these results, the study of the effects on wind shear on piloting problems was made that culminated in 1980 in a revision of the military flying qualities specification. This specification now includes a wind shear model to be used to verify that the flying qualities of new aircraft are such that aircraft upsets due to wind shear are readily controllable.

An environmental hazard which is taking on new significance is lightning, not only because of its damaging direct or physical effects, but also due to the induced electrical effects which can occur even when lightning does not directly contact the aircraft. The electromagnetic fields produced by lightning discharge are capable of inducing currents in inadequately shielded aircraft wiring. When one considers that the trend in aircraft design is toward ever-wider applications of microelectronics for such safety-related items as fly-by-wire flight control, digital engine controls, and navigation systems, the effects of these induced currents can be catastrophic. In a joint program involving all three military services, the FAA, and NASA, efforts are underway to determine the electromagnetic characteristics of lightning, develop lightning simulation techniques for aircraft testing, and develop and validate aircraft protection methods and criteria.

A final environmental hazard I would like to discuss involves our work on aircraft icing. The Air Force and the Army have been developing ice accretion models for both fixed-wing aircraft and helicopters. Models developed to date are capable of simulating ice formation on round objects, but they have not been extended to airfoils as yet. We have also conducted extensive investigations into icephobic materials but with little success. Polyurethane tape tested by the Air Force demonstrated anti-ice properties by working well under moderate conditions and having no ice-release characteristics under severe icing conditions.

I would like to now discuss briefly our work on human factors. I am sure that we can all agree that the improved safety record of aviation in the past two decades is due in part to improvements in the ability of operators to more effectively interact with flight systems. On the other hand, it is clear that aircraft accidents attributed to human error continue to occur. Thus, a continuing program of research into human factors aviation is required.

The human factors of knobs and dials, the old ways that pilots interacted with aircraft, are well established. Now there is a need for research to address the man-computer interaction, because that is the way pilots are increasingly interacting with their aircraft. In order for a modern aircraft system to work effectively, there must be a careful mating of the pilot and systems with which he works. One example of a successful design feature that permits the pilot to cope with an increased amount of information input is the integrated display. This display permits the pilot to see all critical information in a single glance. Information is also projected on a transparent screen so that the pilot can see the display with his head up while still looking at the outside scene. The integrated head-up display has received outstanding acceptance in the field and has been shown to be effective under actual flight conditions.

Within DOD, we are conducting research in a number of areas which, like the head-up display, have the potential to make significant contributions toward increasing flight safety. Some of the examples are helmet-mounted displays which have the same features of head-up displays but move with the pilot's head, particularly applicable to helicopter pilots. We are doing a lot of work in strength and stamina measurements and the physical accommodation of pilots due to the acceptance of female pilots in the Department of Defense.

Before concluding my discussion of our research programs, I would like to observe that integral to DOD flight safety efforts related to the environmental parameters of icing, wind shear, turbulence, lightning, and other severe weather phenomena are the research activities designed to improve observation and forecasting of these hazardous phenomena. The military services research, development, and operational weather service activities are involved in several interservice and interagency joint and cooperative efforts. The key coordinating arena for the environmental support activities is the Subcommittee on Aviation Services within the Office of the Federal Coordinator for Meteorological Services and Supporting Research. This committee is particularly active in weather service effects on aviation safety, as indicated by their February 1982 publication, "A Report on Improving Forecast of Icing Conditions for Aviation."

Aircraft icing research activities are primarily centered in the Air Force and the Army. Army researchers have conducted detailed investigations on icing, ice adhesion, icing of rotating blades, freezing precipitation, freezing rain, sleet, and other forms of natural icing conditions.

Mr. **Gore**. If I could interrupt you briefly, we have a vote on the floor. Mr. Glickman went over earlier, and he should be back here in 1 or 2 minutes, but we are going to have a brief recess for a few minutes, and he will start again when he gets back.

[Recess taken.]

Mr. **Glickman**. I am sorry for the delay.

Mr. **Siewert**. Mr. Chairman, I thought I would just conclude my oral statement by indicating those areas where we believe that additional research is warranted and will have a high payoff.

In the area of aircraft safety, we believe there will be a high payoff from continued work on the development of lightning protection techniques for aircraft and subsystems, nonflammable hydraulic fluids, automatic ground control systems, and the determination of the impact and crashworthy characteristics of organic composite structures.

With regard to human factors, we foresee gains to be made through increased effort in the analysis of advanced integrated displays and controls for optimal cockpit function allocation for automation tradeoffs, development of in-flight workload analysis techniques, and methods and technology for using simulators as an assessment tool in accident analysis and prevention.

In environmental support, we believe continued work is required in ice accretion, focusing on the microphysics of ice adhesion, airframe ice accumulation modeling, and ice removal methods.

Finally, we must continue to improve our capability in weather observation and forecast. Here, the greatest potential lies not so much in increased research but in full implementation of the next generation weather observation Doppler radar program.

Mr. Chairman, this concludes my prepared remarks, and I will be pleased to answer any questions you may have.

[The prepared statement of Mr. Siewert follows:]

THE DEPARTMENT OF DEFENSE ACTIVITIES IN AVIATION AND AIRCRAFT SAFETY RESEARCH

STATEMENT
BY
RAYMOND F. SIEWERT
DIRECTOR, ENGINEERING TECHNOLOGY
OFFICE OF THE UNDER SECRETARY OF DEFENSE
FOR RESEARCH AND ENGINEERING

BEFORE THE
SUBCOMMITTEES ON TRANSPORTATION, AVIATION AND MATERIALS
AND
INVESTIGATIONS AND OVERSIGHT
OF THE COMMITTEE ON SCIENCE AND TECHNOLOGY

UNITED STATES HOUSE OF REPRESENTATIVES
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DEPARTMENT OF DEFENSE

I. INTRODUCTION

Military aviation accidents are, of course, a matter of very real, continuing concern to the Department of Defense. Military aviation, particularly tactical aviation, constitutes a most demanding operational environment. Military aircraft and associated operational systems are designed on the cutting edge of available technology and built to meet complex, exacting requirements of modern air warfare. Aircrews and ground support personnel train rigorously in peacetime to make maximum effective use of aviation system capabilities when and if they are required to do so in combat. This means that our aircraft are operated out to the limits of their performance envelopes. Within those constraints, however, aviation safety is a paramount consideration and an inseparable aspect of operational readiness.

By concerted action over the past 25 years, the Military Departments have achieved a twelve-fold reduction in aircraft accident rates. 1981 was one of the best years ever for military aviation safety.

This remarkable long range achievement has been the product of lessons learned from increasingly sophisticated investigation and analysis of accidents, and resultant, sweeping improvements in aircrew and maintenance training, flight discipline, logistic support, research and development, and application of advanced technology in aircraft design and reliability. In very recent years the rate of improvement has slowed, as the more obvious problems have been solved. Substantial further improvement will require innovative approaches and special efforts, which are current Service priorities.

We devote extensive effort to identify and eliminate, or control, aviation hazards related to the aircraft, operational facilities, human factors, and the interfaces between all three. This effort includes (1) structured hazard analysis and correction at all stages in the system acquisition process; (2) analysis of data and corrective actions derived from investigations of accidents, near accidents, and material deficiency trends; and (3) research, development, and application of advanced technology.

Safety data collection and analysis to support all three efforts is accomplished at the Service safety centers. To provide for direction of corrective effort, accident causal analysis is both general and specific. Attached to this statement is a breakdown of general areas of causal factors for Military Aircraft Accidents over the past five years, with emphasis on the particular areas of interest expressed by your subcommittees. Attached also are some typical examples of specific recommendations and follow-up corrective actions.

II. RESEARCH AND TECHNOLOGY PROGRAMS

A great deal of the safety related research work is oriented toward improved structural design and air worthiness criteria, enhanced in-flight combat survivability and inflight escape, in addition to those areas traditionally associated with safety, such as crashworthiness and post crash fire suppression. The concepts of air worthiness design criteria underly the entire discipline of aircraft design technology covering a far broader area than will be addressed herein. We will review our efforts in the traditional areas of aircraft safety, as well as some of those related to combat survivability, as much of the technology could be applied to increase post crash survivability.

Crashworthiness

Within DoD, the Army has led the way in developing the technology associated with crash survivable aircraft. The concepts employed in designing crashworthy aircraft are more readily applied to helicopters with their relatively low speed and low weights. However, many of the lessons learned can be, and are being applied to higher speed fixed wing aircraft.

The Army's aviation crashworthiness R&D program has spanned more than 20 years. Over this period scores of technical mucorts have been published documenting in detail the results of this program. Army aviation accident data show an impressive decline in accident rate as a result of this R&D, dropping from a high of 37 accidents per 100,000 hours in 1962 to 7 per 100,000 hours in the late 70's. Accident data review indicates that approximately 90 percent of all accidents involving Army helicopters were potentially survivable by the occupants. Even during the Southeast Asia conflict, there were almost as many losses due to accidents as were attributable to the enemy. Helicopter combat losses from January 1967 to May 1970 were 1433 while noncombat losses were 1421 and there were 1453 fatalities.

The Army program began with a study of data from hundreds of accidents, accident investigations, and full-scale crash testing. From this we acquired an understanding of crash impact conditions and consequent hazards. Design concepts, techniques, and criteria were developed and substantiated through testing. A total of 41 full-scale aircraft crash tests have been performed by the Army to date, the latest being conducted in July 1981 and involving an advanced attack helicopter.

Army R&D programs in the areas of crashworthy fuel systems, seats, restraint systems, airframe, landing gear, and emergency egress led to the publishing in 1967 of the Army's "Crash Survival Design Guide." The latest revision was published in 1980 and was extensively coordinated within the Army, Navy, Air Force, NASA, the FAA and industry. This current revision, the fourth, contains the most comprehensive treatment of all aspects of aircraft crash survival now documented and is in demand by aircraft developers both nationally and internationally. It can be used as a general text to establish a basic understanding of the crash environment and the techniques that can be employed to improve chances for survival.

The essence of crashworthiness is to employ a number of components such as landing gear, crushable belly structure and energy absorbing seats all functioning together as a system which uses all of the available stopping distance to bring about a controlled deceleration of the aircraft occupants. The system is designed to perform this role so that decelerative loads are within human tolerance (without injury) for 95 percent of the survivable accidents. This process is aided by the use of an inflatable body and head restraint system (IBAHRS) currently under development which is triggered by the crash pulse to inflate automotive type air bags within the restraint system shoulder straps which tightens the occupant restraint system thus reducing the pilot's strike envelope. Human tolerance limits are being explored in joint efforts with the Navy, Air Force and the FAA. In the area of crashworthy seats, the Army has developed energy absorbing crew seats, troop seats and gunner seats, with the crew seats currently being installed in the Black Hawk helicopter.

The "proof of the pudding" of these various energy absorbing features for modern Army helicopters is our full-scale crash testing. Through a relatively inexpensive crash test (residual prototypes are normally used), a great deal can be learned about "real world" crash conditions that cannot be duplicated in laboratory component tests. Also, of the 41 tests performed to date, the last three have had their structures mathematically modeled and dynamically simulated by the Army-developed computer program "KRASH" with refinements to the program based on actual test results. The goal is to adequately develop the model so that it can be eventually used as a design tool to optimize crashworthiness features in new aircraft and replace the more expensive full-scale crash testing. Our July 1981 crash test of a YAH-63 attack helicopter was of extreme usefulness in evaluating approximately ten Army, Navy and NASA crashworthy improvements that may find both military and civilian application. We have also recently conducted the first full-scale fuselage drop tests (two) of fuselage sections constructed of lightweight composite materials. A full-scale crash test of a complete helicopter airframe made of composite materials is scheduled during FY 1984. Research has been done to determine the energy absorption of selected floor panel designs. Aluminum skin-stringer, honeycomb sandwich and a composite design were subjected to static and dynamic testing. The results of this testing demonstrated that peak accelerations can be reduced by using appropriate materials and design.

Fire Protection

Military aircraft fire protection R&D emphasis is directed at the enhancement of in-flight combat survivability and resolution of selected operational fire mishap problems. Although the aircraft cabin fire hazard is an area of conern, the long-standing, comprehensive and impressive NASA and FAA programs related to interior cabin materials, fire propagation and related human survivability aspects have been addressing the pertinent issues.

Fuel Flammability

Efforts to evaluate the use of a safer fuel than the standard JP-4 fuel for combat operations, as well as for improved ground handling safety, were started by the U.S. Air Force in 1967. Combat losses directly related to fuel fires or explosions during the Southeast Asia conflict supported the basis for evaluation of a more combat-safe fuel. JP-8 (NATO Code F-34) which is essentially commercial Jet A-1 with fuel system icing inhibitor and corrosion inhibitor added, has undergone extensive testing under both laboratory and full-scale tests and has been proposed for military application worldwide. Significant and favorable volatility properties of JP-8 are a vapor pressure of 01.10 psi at 38°C and a minimum flash point of 38°C which normally exceeds ground handling temperatures. In comparison, JP-4 has a vapor pressure of 2 to 3 psi at 38°C and a minimum flash point of less than -20°C.

In the mid 1970's, efforts were started and are continuing to make JP-8 the standard fuel of the NATO air forces in Europe. U.S. Air Force bases in the United Kingdom completed conversion to JP-8 in August 1979, but conversion from JP-4 to JP-8 in NATO Europe has been delayed due to concern of some nations over the higher cost of JP-8 versus JP-4. In addition to safety advantages of JP-8 versus JP-4, interoperability of NATO air forces would be improved since European commercial aviation carriers use the equivalent Jet A-1.

During the past 15 years considerable research and development programs have been performed in the U.S. and the U.K. to develop modified fuels for reduction of the post-crash fire hazard. Specific approaches have included gellation and emulsification and incorporation of antimisting additives. Results of these programs have shown that any practical fire safe fuel concept must utilize a low volatility fuel, such as JP-8, Jet A-1 or Jet A, as the base fluid. Reductions in misting characteristics have been found by gelling or emulsifying fuels, but these methods are severely lacking in other critical aspects (holdup of fuel in the aircraft tankage and pumpability problems). The antimisting additive approach appears very promising and is being pursued in a cooperative manner by the U.S., FAA and the U.K. An extensive engineering and developments program is underway by the FAA to complete all research necessary to support a notice of proposed rulemaking to be completed by mid 1984 for the introduction of antimisting resource fuel into civil aviation use. Although DoD is not presently performing R&D in this area, we are monitoring FAA's program for possible application to the military air fleet.

Helicopter Crashworthy Fuel Tanks

The Army has developed a crashworthy fuel system as the primary solution to the post crash fire problem in helicopters. This system consists of replacing the old bladder fuel tanks with a new nylon laminate fuel tank which meets the crashworthy criteria established for helicopters. For a three-year period (1967-1969) prior to installation of the crashworthy fuel system, there were 1000 survivable helicopter accidents in which fires occurred in 13.3 percent of these accidents and 59.7 percent of the fatalities were due to fire. After incorporation of the crashworthy fuel system beginning in 1970, there have been no thermal fatalities resulting from failure of the crashworthy fuel system.

The Navy is developing self-sealing bladder fuel tanks for the CH-46 Marine assault helicopter. The tank is designed to withstand a severe 60-foot drop test without exhibiting any leakage. Retrofit of these tanks into the existing helicopter fleet will greatly reduce the fire hazard in a survivable crash.

Fuel Tank Explosion Protection

Aircraft fuel tank explosions can occur during normal operation or combat encounters. The C-5A aircraft utilizes liquid nitrogen inerting for fuel tank explosion protection which, to date, has been credited with saving one C-5 aircraft. An on-board inert gas generator system (OBIGGS) currently under development by the Air Force would provide the same level of protection, but at significantly lower logistics and weight penalties. The OBIGGS uses engine bleed air as the air source which is then conditioned with ECS type components prior to separation of the nitrogen from the oxygen. Separation may be accomplished either with a permeable membrane or with a molecular sieve module. Extensive full-scale ground testing of both type systems will be conducted during FY 82/83. Flight tests, the last step prior to operational applications, could be conducted in FY 84 if funds are approved. OBIGGS could also be cost effective for commercial aircraft explosion protection and also provide some post crash fire protection.

In a related Navy program, the use of a nitrogen enriched atmosphere in the void spaces adjacent to the fuel tanks to eliminate the potential for fuel vapor explosion is being investigated.

Both Air Force and Navy combat aircraft employ fuel tanks lined with reticulated foam to suppress fuel tank explosions resulting from combat damage. In addition, the Navy operational practice is to use JP-5 fuel while at sea, due to its reduced flammability.

Nonflammable Hydraulic Fluid Development

The Air Force experienced over 179 aircraft hydraulic fluid related fires over the period 1965-1981. These fires were due to the ignition of MIL-H-5606 hydraulic fluid (petroleum base). Several personnel and aircraft have been lost due to these fires. Since 1975 the Air Force Wright Aeronautical Laboratories have been developing a new nonflammable hydraulic fluid for future Air Force aircraft. The development program has identified and tested an excellent candidate fluid-halo-carbon AO-8 which is a cholofluorocarbon (CTFE) base material. Present programs are being conducted to improve the CTFE fluid lubricity, antiwear and viscosity properties, develop compatible elastomers and determine necessary component and system design changes. Technology availability date is projected for 1986-1987.

AIRCRAFT LANDING CONTROL/TRACTION

One of the problem faced by modern high performance aircraft is staying on the runways during adverse weather conditions; that is runways made slippery by rain, snow, or ice, coupled with heavy crosswinds. The Military Services have been doing research over the past several years to address this problem.

Advanced Ground Control System

As aircraft ground operating speeds and gross weights have increased and pilot sensory feedback decreased, pilot ability to control the aircraft has been pushed to the limit. One solution to this problem is an automatic control system to relieve much or all the pilot workload at high speeds in adverse conditions. This system would work on the ground much like the flight control system of modern fighters like the F-16 works in the air. In its present concept, the system would control the steering, braking, and rudder of the aircraft to maintain directional control, lateral position, and to brake the aircraft to a stop. Other control functions, such as reverse thrust, could be added as required for a particular application. Feasibility of the concept was established under contract by Boeing. In that program, Boeing predicted vast improvements in adverse weather operating capability for the study aircraft, an F-4, based on computer simulations. A follow-on effort, currently underway, will evaluate the control system performance in comparison with human pilots on the Air Force LAMARS motion based piloted simulator. Subsequently, the system will be demonstrated on an aircraft.

Tire Traction

A radial tire program addressing improved aircraft handling, and in addition, life cycle cost, is the development of an aramid fiber aircraft tire. Aramid cord has the essential properties needed for radial aircraft tire construction because of its high strength, high modulus, excellent heat resistance and low growth properties. Improvements are expected from increased tread life, a minimum 15 percent reduction in tire weight, and increased tire reliability. Performance improvements are expected from increased traction and cornering capabilities provided by the aramid reinforced/radial aircraft tire. A number of tire design, fabrication test and evaluation iterations have been performed to establish radial aircraft tire design criteria. Based on the most promising designs obtained in the latest phase of the program, radial tires for the fighter application (F-4 MAIN WHEEL) will be fabricated and subjected to laboratory qualification testing. Refinements required to produce a fully qualified/flightworthy radial aircraft tire will be identified under the current program.

Siped Tire

Another way of improving the traction of aircraft tires is tire tread siping, developed by Marcy, Inc. Siping is a process wherein small slits are cut in the tread surface of the tire. This concept is currently being laboratory and track tested by the Air Force, Navy and FAA. Testing to date has shown significant improvements in wet surface traction without compromsing high speed tread integrity. The Navy is also investigating siped tires to improve traction on ship decks, particularly in heavy seas. Future work tentatively includes an operational fleet evaluation by the Navy to determine tread wear effects and to obtain actual aircraft performance data.

Landing Aids

The Navy is developing a shipboard landing aid to assist the pilot in maintaining the proper approach path. The current visual landing aid is being modified to provide additional rate data, to reduce pilot work load, resulting in safer landings, particularly at night. This work is being coupled with a ship trailing air wake turbulence model to predict where possible upsetting moments will occur.

NATURAL HAZARDS

Wind Shear

Modeling/Specifications - Analytical research efforts during the 1973-74 time period yielded a computer model of atmospheric wind shear and turbulence and airplane generated wake vorticity. This model was to be used with a dynamic mathematical model of military aircraft to examine both the response to these phenomena as well as the ability of the airplane to be controlled through the disturbances. Based on such information, flight control design methods could be developed and specifications revised that govern control system design to assure safety during flight in such disturbances. In 1976, the work on modeling these disturbances was split, part being concentrated on wake vortices and part on wind shear. The wake vortex work yielded technical reports, safety bulletins, a safety training film produced by Norton AFB, training simulator programs, and safety inserts in all Air Force aircraft flight handbooks by the Logistics Command. The final product in the wake vortex area was in 1980. The safety office at Norton reported that these efforts have reduced wake vortex related accidents to a level that futher reductions are unlikely. As a result, this work has been terminated. The wind shear modeling work continued, examining critical combinations of changes in wind speed and direction with altitude. Four critical combinations were indentified and the information documented in a technical memorandum in 1977. Based on these results, a study of the effects of wind shear on piloting problem was made that culminated in a revision to the Flying Qualities Specification, MIL-F-8785, which was coordinated throughout DoD and published in November 1980. The revised specification now includes the model of wind shear to be used to verify that the flying qualities of new aircraft are such that aircraft upsets due to wind shear are readily controlable. This makes countering wind shear a design requirement in the Flying Qualities Specification. Continual communication, with DoT and the FAA, was maintained throughout these efforts. The results have been made available to them and the specification forms part of the basis for the design of commercial aircraft. Future work will include further validation of the specification using manned simulations.

Flight Research - Flight research efforts during the mid 1970's were performed in support of a large FAA Wind Shear program under an ongoing USAF/FAA Interagency Agreement (DoT-FA70WA1-173). Under the USAF C-141 All Weather Landing System (AWLS) program wind vector data were recorded in a number of terminal areas having reported wind shear conditions. These data were utilized by the FAA to refine existing wind shear models for simulation research and analysis of ground and airborne detection concepts. In 1978, the Laboratory was requested by FAA to perform a flight evaluation of a low-cost, prototype wind shear advisory system developed in-house by the FAA. Prototype equipment was installed in a C-135C which was designed to detect the doppler shift of a modulated signal superimposed on the localizer portion of a modified ILS transmitter. Range rate or ground velocity information was thereby obtained and available for comparison with air-speed data to provide pilot alert of wind whear penetration. Comparison of this derived ground-speed with on-board inertially computed velocity data from a high accuracy inertial navigation system indicated highly acceptable performance with deviations on the order of 1 to 2 knots. Successful flight demonstration of this concept provided needed confirmation to the FAA for release of a proposed rule for equipping commercial carrier aircraft with suitable instrumentation for effecting safe low-level operations in wind shear conditions. This work was completed in 1981 and no further wind shear R&D is underway or planned in this area.

Lightning

Lightning is a dual hazard to aircraft because of its damaging direct, or physical effects, and because of the induced electrical effects which can occur even when lightning does not directly contact the aircraft. The most obvious direct effects are physical damage--erosion, deformation and burnout--of the aircraft structure caused by extrement heat loading, acoustic shock and magnetic forces arising from high lightning currents. The most frequent direct effect damage occurs at radomes, pitot booms, canopies, external antennae and wingtips. Lightning-induced indirect damage to aircraft is caused by the rapidly changing electromagnetic fields produced by the lightning discharge. Such fields are capable of inducing currents in inadequately shielded aircraft wiring with effects that can range from minor to catastrophic.

Over the last decade, outstanding improvements in aircraft performance have been realized. This progress is, to a great degree, attributable to two fast-advancing technologies: Microelectronics and advanced structural materials. Consistent with the use of these emerging technologies has been a change in aircraft design philosophy, so as to take the fullest advantage of the benefits that the technologies might offer. Concepts such as fly-by-wire, digital engine controls, and propulsion/ flight control integration, to name but a few, have become a reality. The trend to the future promises even greater capabilities. However, the incorporation of these technologies in the new generation aircraft is not without some attendant concern. As pertains to the lightning hazard, the concern has prompted a comprehensive examination of the impact of electromagnetic coupling on the safety of flight of advanced systems. The evidence appears to indicate that electronic flight-critical and mission-critical avionics which are to be used in advanced military and civilian aircraft are more sensitive to upset, malfunction or physical damage; and are to be used in airframes which allow increased levels of coupling energy to pass through the skin to those internal avionics.

Lightning-related research and developmant at the Air Force Flight Dynamics Laboratory has been pursued to investigate both the direct and indirect effects. The direct effects activity has been focused on composites to determine the interaction of lightning with advanced structures. These programs have concentrated on determining the direct effects of lightning including the burning and blasting effects on the structure as well as the indirect electromagnetic effects of lightning on internal subsystems. Design guidelines have been formulated and protection techniques developed to aid the aircraft designer in effective lightning protection for advanced structures. These criteria have most recently been applied in the design of the commercial Lear Fan 2100 aircraft.

Within the indirect and induced effect area, there is a combined DoD/NASA/FAA effort that addresses the three basic requirements for the development of protection technology: (1) a detailed determination of lightning electromagnetic characteristics, (2) the development of lightning simulation techniques for aircraft testing based upon the determined threat and (3) the establishment of aircraft protection criteria and guidelines for use by both the military and civil sectors alike. Lightning characterization and simulation development have received primary emphasis to date. Key gaps in the lightning characterization data base are presently being filled by measuring lightning pulse electromagnetic fieds. The data from the characterization effort will directly affect the design of lightning test simulators. Simulators capable of approximating some effects of lightning have been constructed within DoD, and have been used to support customer testing needs throughout the Federal R&D establishment. Aircraft tested to date include the F-4, YF-16, F-16, F-104, A-7, T-39, Learjet, C-130, F-111, T-38, NASA T-38, and the NASA F-8 Fly-by-Wire. Plans are also being made to test the F-14 and F-18. Development of an improved simulator is presently underway to incorporate findings from the most recent characterization efforts, which indicate that the lightning threat to aircraft is considerably more severe than previously anticipated. The data and technology developed will be used to support an Advanced Development Program (ADP) for aircraft protection, which will begin in 1982. The ADP will address the selective integration of protection techniques and the procedures for validation and certification of the protective measures incorporated. These techniques and guidelines will have application to military and commercial aircraft, space vehicles and ground equipment. Through the use of the guidelines developed, the new technologies which so vastly improve system performance may be incorporated with confidence that the threat of lightning has been eliminated.

Ice

The following programs are recent DoD efforts concerning the atmospheric and aerodynamic processes involved in aircraft icing and the effects of heavy rain:

Ice Accretion Model - A computer program has been developed to numerically simulate the physical processes associated with ice formation on solid objects. The model is unique in its ability to handle the flow of individual cloud droplets. This is an important aspect in determining the final shape of ice buildups on objects such as airfoils. The model also has the ability to simulate the thermodynamic processes and growth of both rime ice and clear ice. The current program is successful in simulating ice formation on round objects, but it has not been extended to airfoils.

Aerodynamic Penalty Model - A computer program has been coded to analyze the lift and drag penalties due to ice formation on aircraft. The model incorporated both atmospheric data, specific airfoil characteristics, and flight characteristics. The model uses empirical relationships based on 1950 era NACA reports. A recent attempt to validate this model with instrumented research aircraft data ended in inconclusive results. In its present form it is not accurate enough to predict performance degradation due to icing.

Anti-Ice Materials - An Air Force research program is ongoing to identify coating materials which reduce the amount of ice formation on aircraft during flight. These materials are termed icephobics. In initial tests, 60 candidate materials were evaluated. Of these products, two were identified as having some icephobic potential. These two products were recently tested in high speed icing wind tunnel tests. One product, a silicone grease, failed the tests due to erosion. The second product, a polyurethane tape, demonstrated inconsistent anti-ice properties, working well under moderate conditions but having no ice release characteristics under severe icing conditions.

Rotorcraft Icing - Because of the pervasiveness of icing conditions in the Navy environment, electrically heated deicing blankets are installed on the rotor blades of all Navy helicopters. The Army has defined meteorological design criteria and developed advanced rotor blade ice protection concepts which include electrothermal, vibratory, microwave and ice phobic coatings. They have tested and evaluated virtually every rotary-wing aircraft in the Army inventory as well as several of the fixed-wing aircraft. In short, the Army is well aware of the aircraft icing problem and its impact on airmobility and has a comprehensive, structured program which includes research, development, flight test and evaluation and addresses virtually all Army aircraft.

Birds and Wires

Air Force aircraft repeatedly prove that birds and aircraft cannot occupy the same airspace at the same time; 1000 to 1500 birdstrikes per year cause millions of dollars in damage to USAF aircraft. During the past 12 years at least nine military pilots have been killed and 15 aircraft destroyed due to bird impact. By far the majority of these losses are due to windshield system and engine impacts. Design guidelines, test technology and hardware are being developed and applied to enhance aircraft bird impact resistance. Windshield systems providing improved birdstrike resistance have been or are being developed for application to several operational aircraft including the F-111, F-16, T-38, T-37 and F-4. Transparency technology investigations are being conducted to support these systems related developments and to provide a technical base for cost effective development of transparency systems for new aircraft or for modification of existing aircraft. The F-111 and F-16 windshield system resistance against four pound birdstrikes has been increased from about 150 knots to 500 knots and 350 knots respectively. At least 10 F-111 saves are already credited to use of the new transparencies. The T-38 windshield system birdstrike resistance is being increased from 150 knots to 400 knots. Engine system technology investigations are being conducted to provide a means of incorporating and evaluating birdstrike resistance during the early phases of engine design Finite element computer programs are being developed and evaluated for application to the windshield and engine birdstrike problem areas.

The Army is continuing to pursue solutions to flight safety problems which result in preventable accidents. A good example of this is recent work performed to test a simple cost-effective wire strike protection system (WSPS) for the OH-58 and the UH-1H helicopters. During the 5-year period beginning 1 January 1974, wire strikes accounted for 8 percent of total Army aircraft damage, 6 percent of all injuries and 16 percent of all Army avaiation fatalities. Emphasis on operations requiring flight close to the ground make wire strikes an ever-present combat and training hazard. The WSPS is a lightweight (16.3 pounds) cable cutting retrofit system that has been successfully tested on the aforementioned two types of Army helicopters and is currently being tested on the AH-1S attack helicopter. Retrofit kits for the OH-58 are already being installed in the field. It is planned that all helicopters in the Army fleet will eventually be outfitted with the WSPS kit.

HUMAN FACTORS

The improved safety record of aviation in the past two decades is due in part to improvements in the ability of operators to more effectively interact with flight systems. On the other hand, it is clear that aircraft accidents attributed to human error continue to occur and, thus, a continuing program of research in the human factors of aviation is required. The Department of Defense conducts an active program of research and advanced technology development in the human factors of aviation systems in all three Services, with each Service mostly concentrating on topics particular to their needs. In most cases, the results of the research are also applicable to civil aviation.

Microprocessor technology exerts and will continue to exert great influence on the way aircraft are controlled. With the new potential that microprocessors create for more automated flight operations, comes the need to examine how computers can best operate to most effectively interact with the human pilot. With the rapid growth of automation, computation, and display, the human pilot is becoming a supervisor and monitor of computers, which, in turn, control the aircraft. Pilots are now flight managers as well as the more traditional skilled manipulators of flight controls.

The human factors of knobs and dials, the old ways that pilots interacted with aircraft, are well established. Research funded and conducted by the Department of Defense was instrumental in developing the human engineering guidelines that are now routinely applied to this type of man-machine interaction. There is now also a research need to address the man-computer interaction because that is the way pilots are increasingly interacting with their aircraft.

A common misconception is that because flight is becoming increasingly automated, there is less reliance on pilots for the safe performance of aircraft. In fact, today's pilot requires more skills than the pilot of the past. Not only must he be able to operate the new, advanced technology avionics systems that his predecessor did not have, but he must also be capable of operating the aircraft when the advanced systems fail, and all of this must be done with more maneuverable and faster aircraft that have smaller control surfaces and more ambitious missions.

In order for a modern aircraft system to work effectively, there must be a careful mating of the pilot and the systems with which he works. One example of a successful design feature that permits the pilot to cope with an increased amount of information input are the multi-purpose head-up and head-down displays. For example the pilot, using a head-up display does not have to look down at the console to check instruments and thus remove his attention from the outside scene, and has an image of the relevant instrument or information projected much closer to where he is currently attending. Multi-purpose displays have received outstanding acceptance in the field and have been shown to be effective under actual flight conditions.

The Services are currently conducting research in a number of areas which, like multi-purpose displays, have the potential to make significant contributions towards reducing pilot workload. Some of these efforts are briefly described below:

- Techniques to Measure Workload: These efforts seek to predict pilot workload based on an analysis of the hardware and observations of similar systems. The analyses are performed as a function of specific mission profiles. The results of these analyses are used to identify operability problems and hazardous situations prior to full-scale production.

- Helmet-Mounted Displays: Just as head-up displays made it possible for pilots to operate without looking at the console, helmet-mounted displays permit pilots to have an information display that moves with them when they look at the side. This is particularly important in helicopters where the pilot may be moving at a slow speed and looking for targets in any direction.

- Voice Interactive Systems: While head-up and helmet-mounted displays mainly address the problem of input overload to the pilot, voice interactive systems permit the pilot to control the aircraft using vocal commands. The potential advantages of vocal commands over switches and knobs is speed, accuracy, and comptability which should contribute to reduced workload in the near-saturated visual/motor channels. The human factors problem is to determine whether pilots can effectively interface with such systems.

o Cortical Evoked Potentials: Research is being conducted to determine the value of changes in brain activity as determined by cortical evoked potentials to identify key points in mission profiles that cause operator overload. This information would then be used to redesign controls or procedures for more effective uses of human capabilities.

In addition to the research on the human factors of pilot workload, the Services are conducting research in other areas where human factors technology has the potential of contributing to flight safety. These efforts are described below:

o Hazardous Condition Simulation: Flight conditions that lead to accidents or near-accidents are too hazardous to recreate in flight. Researchers, therefore, are developing a simulator to determine both the exact conditions under which accidents occur and methods of avoiding accidents.

o In-Air Visual Acquisition Capability: Research as suggested that certain characteristics of the human visual system such as empty field myopia, which results when pilots scan open, unstructured sky for another aircraft could affect pilot performance. The objective of this effort is to isolate environmental and pilot-related parameters that cause the problem and to develop training techniques to reduce its effects.

o Dynamic FLight Simulation: Under certain conditions, pilots may be tragically unaware that their aircraft are in a spin. Research being conducted with centrifuges seeks to identify the conditions under which spins are not apparent and to develop techniques for avoiding these conditions.

o Human-Oriented Mishap Reduction System: Research in this area seeks to enhance mishap and near-mishap investigative techniques. Information from the improved data base will contribute to identifying hazardous conditions.

o Strength and Stamina Measurements: Recent research indicates that male-determined norms for pilot strength and stamina may not be appropriate for female pilots. Efforts are being made to redefine strength and stamina requirements for female pilots.

o Physical Accommodation of Pilots: This topic includes a variety of research with the objective of increasing the physical comfort, convenience, and safety of the pilot and aircrew. Active research programs are involved with more effective ejection seat design, better cockpit design, and improved restraint systems.

o Circadian Desynchronosis: The research, conducted jointly with NASA, indicates that disturbances to the sleep/wake cycles caused by long flights affects fatigue and actual performance. Future research will seek to develop methods to minimize those effects.

AEROMEDICAL CONSIDERATIONS

The Air Force Aerospace Medical Research Laboratory has a long history of fundamental and broad spectrum research to improve crew safety during aircraft emergencies. These activities range from primary biotechnology efforts to define the strength of human tissues under rapid load conditions to the evaluation of life support equipment such as restraint systems that are currently being developed for operational aircraft. The research is conducted using nationally unique laboratory equipment and facilities including a 250 ft horizontal impact track and a 60 ft vertical deceleration tower. The products of this research program support other Air Force laboratories, Air Force system acquisition organizations, and have been used by other Government agencies such as the Department of Transportation, National Highway Traffic Safety Administration, NASA Manned Spacecraft Center, U.S. Army, and U.S. Navy.

Specific experimental research programs that are underway at this time include efforts to: (1) define the strength of the human spine under impact laods, (2) develop new mathematic models to describe and predict human responses to impact and windblast, (3) demonstrate the feasibility of reducing the time required to eject crewmembers from disabled aircraft, (4) conduct impact tests of existing and new ejection seat restraint systems using volunteer subjects, (5) determine the aerodynamic forces acting on an ejecting crewmember under high-speed escape conditions, and (6) demonstrate the adequacy of new restraint system prototypes under 40G crash loads. Other ongoing research efforts include the development and evaluation of new impact and windblast protection principles and techniques. Prototypes of body support and restraint systems are designed and built by contractors and then evaluated by extensive laboratory tests. The results of these efforts are used to develop design criteria for advanced protection systems. These criteria are specified in terms of human impact and windblast exposure limits, design and test standards, design handbook data, and evaluation procedures and specifications.

ENVIRONMENTAL SUPPORT

Integral to the DoD flight safety efforts related to the environmental parameters of icing, wind shear, turbulence, lightning, and other severe weather phenomena, are the research activities designed to improve the observation and forecasting of these hazardous phenomena. The military Service research, development and operational weather service activities are involved in several interservice and interagency joint and cooperative efforts complementing those joint efforts discussed earlier. The key coordinating arena for the environmental support activities is the Subcommittee on Aviation Services (SC/AS) of the Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR) within the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM). The DoD is a major participant of the subcommittee. This committee is particularly active in the weather service effects on aviation safety as indicated by their February 1982 publication "A Report on Improving Forecasts of Icing Conditions for Aviation."

The R&D activities related to the DoD environmental support services will be discussed by the parameter of interest; icing, lightning, wind shear, turbulence and other severe weather phenomena.

Icing

Aircraft icing research activities are primarily centered in the Air Force and the Army. The Navy's efforts are primarily associated with supporting the FAA helicopter icing studies through the use of an instrumented P-3 aircraft and with an experimental evaluation of surface implanted sensors to determine water depth and ice on runways. The Army efforts center about activities at the Cold Regions Research Engineering Laboratory (CRREL) and the Army Aviation R&D Command (AVRADCOM).

The CRREL researchers have conducted detailed investigations on icing, ice adhesion, icing of rotating blades, freezing precipitation, freezing rain, sleet, and other forms of natural icing conditions. Also, studies have been performed on the physical properties of ice, ice accumulation rates, and methods of snow and ice removal from roads and runways. CRREL's work in the area of forecasting of icing conditions is part of a general effort that addresses the total problem of aircraft icing with strong emphasis on helicopter icing problems. CRREL has developed a numerical simulation of icing accretion rates in terms of the structure parameters and the atmoshperic parameters of temperature, liquid water content, and drop size distribution. This allows evaluation of the sensitivity of accretion to each of these. CRREL is also initiating work on forecasting of icing at the mesoscale with the intent of eventually providing the tactical commander with local forecasts of icing probability for combat display rathan than "blanket" forecasts. This work will support the combat processing and display software being developed by the Army Atmospheric Sciences Laboratory under the Tactical Weather Intelligence program.

The Air Force has a small but significant aircraft icing program at the Air Force Geophysics Laboratory (AFGL). This program is specifically designed to improve the techniques for forecasting aircraft icing conditions. There are five phases of this research: (1) the evaluation of the Rosemount ice accretion detector for aircraft; (2) the 1979-81 collection of detailed data sets using an HC-130 aircraft flying in icing conditions within the vicinity of a rawindsonde balloon station; (3) the comparison of these icing data with the current Air Force Air Weather Service (AWS) icing forecasting techniques; (4) the development of improved techniques using standard available meteorological data as input; and (5) the development of a method for producing a worldwide climatology of aircraft icing based on standard archived data. The Air Force AWS has the responsibility for operational aviation forecasting for both the Air Force and the Army. In a related effort to that within AFGL, the AWS is working to improve its ability to forecast the key meteorological input parameters for icing forecasts: enroute temperature, cloud occurrence and cloud liquid water content. The ability of any icing forecast method is only as good as the basic meteorological input parameters. The improvements achieved in forecasting these basic parameters at the Air Force Global Weather Center will couple with the AFGL and the CRREL work to improve DoD capability for forecasting both fixed wing and helicopter icing conditions.

Turbulence/Severe Weather

Research and development into aircraft in-cloud turbulence is most active within the Air Force. In conjunction with NASA, AFGL has been conducting tests with a ground based doppler radar and instrumented NASA F-106B aircraft at Wallops Island, Virginia, to collect the data needed to develop on board sensors for turbulence avoidance and to improve forecasting techniques. The AWS is currently evaluating the Air Force Flight Dynamics Laboratory (AFFDL) comparative analysis of turbulence impacts on various types of aircraft within similar meteorological conditons. Since the meteorological conditions which cause severe turbulence for a T-39 will have a different result on a C-5 or B-52, each as a function of inflight gross weight, AWS will use the AFFDL report to develop a standard to scale from and more accurately report and forecast aircraft turbulence.

The most significant DoD program related to observing and forecasting the major parameters related to aircraft safety (i.e. turbulence, lightning, wind shear, hail and icing) is the joint DoC/DoD/DoT Next Generation Weather Radar (NEXRAD) Doppler radar program. With many of the benefits and operational complexities of the Doppler weather radar already demonstrated in a joint operational test, the NEXRAD program offers an existing stateof-the-art advance over our current thunderstorm/tornado and associated severe weather phenomena forecasting immediately upon installation. The NEXRAD radars are required to replace the failing 1950's technology radars inservice today. These new radars offer improved tornado lead times (from a current lead time of less than one minute to an average of 20 minutes), doubled detection rates for the severest storms, reduced false alarm rates for thunderstorm severe winds and hail (up to a 50 percent reduction), improved low level extreme wind shear identification and forecasting, improved icing level location, and improved hail forecasting. The AFGL in conjunction with the joint NEXRAD program office and the NOAA National Severe Storms Laboratory is developing and testing the software to automatically identify and forecast these critical severe weather phenomena using the NEXRAD basic Doppler input data.

Lightning

In addition to the aircraft lightning strike research previously discussed regarding the effect on the aircraft, the Navy has an active program focused more toward the detection and location of lightning. The Naval Air Development Center is evaluating an on-board severe storm avoidance sensor for the P-3 anti-submarine warfare aircraft. This low cost passive detector will be flight tested at the Naval Air Test Center this year in conjunction with the Wallops Island ground based lightning detection and ranging system. The P-3 aircraft, due to its number of flight hours flown and mission profile, is the most frequently lightning struck aircraft in the Navy inventory. This system will allow passive navigation around lightning activity which is often important for an aircraft not desiring to emit radar signals. The joint NASA/AFGL icing test at Wallops Island is also designed to evaluate the airborne lightning hazards with respect to the measurable meteorological parameters. The Navy is now in engineering development of a Lightning Position and Tracking System (LPATS) developed by the Office of Naval Research with Naval Air Systems Command assistance. This ground based system detects the unique broad based magnetic field waveform of the cloud-to-ground lightning stroke and displays its location, intensity and movement on a video screen. The LPATS system is currently undergoing field tests at NAS Cecil Field, Florida, with the central station located in the Naval Oceanography Command Detachment office for operational evaluation.

Whatever the environmental aircraft flight safety hazard, the DoD is involved in evaluating and improving the observation and forecasting of the phenomena. In most cases, the DoD efforts are either joint or complementary efforts and coordinated through the Office of the Federal Coordinator for Meteorology and Supporting Research.

FLIGHT DATA RECORDERS

The Navy is equiping the F/A-18 aircraft with a new digital flight data recorder system to provide more reliable data presentation and in greater detail. In addition the Army is continuing to search for better tools to improve its aircraft accident investigation ability. Presently, no type of crash recording devices are installed on Army aircraft. Over the past three years, however, the Army has been identifying the benefits and initiating hardware development of a device which will combine several functions: crash recording, events history recorder, component condition monitoring, and maintenance support capabilities. Called the Flight and

Maintenance Information System (FAMIS), this device will be a considerable improvement from foil or tape records used in airline service. It will have a rugged, completely solid-state (no moving parts) memory with capability to measure and record approximately 36 flight and impact parameters along with monitoring functions. These parameters can identify unsafe maneuvers, detect material failures and provide factual data for accident investigation purposes. A brass-board model of the Accident Information Retrieval System (AIRS), a part of the FAMIS system, has been developed and flight tested.

III. AREAS FOR FURTHER RESEARCH

Great strides have been made toward reducing the number of military aircraft accidents and similar accomplishments have been made in reducing the number of fatalities and injuries, should an accident occur. However, there is still room for improvement, if we are ever to attain the goal of reducing accidents to the irreducible minimum. Some of the areas we feel offer the most payoff are:

AIRCRAFT SAFETY

- o Continued work on lightning hazard characteristics and development of lightning protection techniques for aircraft and subsystems.

o Development of non-flammable hydraulic fluid.

o Demonstration of an advanced automatic ground control system. Future military aircraft will have totally integrated control systems, including propulsion control and thrust reversers, thereby facilitating the implementation of an automatic ground control system.

o Determine the impact and crashworthy characteristics of organic composite structures. All new military aircraft will incorporate considerable amounts of graphite epoxy structure which has considerably different impact characteristics from metal structure. The Army has initiated tests toward developing the data base we must have if we are ever going to develop crashworthy designs from these materials. More has to be done.

HUMAN FACTORS

o Increase effort in the human factors analysis of advanced integrated displays and controls for optimal cockpit function allocation for automation trade-offs.

- Continue development of inflight work load analysis techniques and the quantification of aircrew stress factors.

- Develop methods and technology for using simulators as an assessment tool in accident analysis and prevention.

ENVIRONMENTAL SUPPORT

- In the area of weather observations and forecasting as it relates to aircraft safety, the greatest potential for improvement lies not so much in increased research but in the full implementation of the NEXRAD Doppler radar program.

- In ice accretion, further research is needed on the microphysics of ice adhesion, airframe ice accumulation modeling, and the ice removal methods from airframe and runway surfaces.

Attachments

DEPARTMENT OF DEFENSE
AVIATION MISHAP EXPERIENCE

	CY 77	78	79	80	81
CLASS A MISHAPS	255	257	251	246	225
FATALITIES	223	266	172	211	236
CAUSE FACTORS*					
HUMAN FACTORS					
Crew	148	147	153	138	118
Maintenance	19	26	20	19	11
Supervision	63	75	73	63	53
WEATHER					
Restricted Visibility	14	13	12	3	6
Low Ceiling	3	6	1	8	6
High Winds	3	7	4	1	7
Storms	1	0	5	1	4
Wet Runway	4	4	11	5	2
Turbulence	2	2	3	1	0
Night/No Horizon	4	4	1	4	2
Lightning	0	2	1	1	0
Icing					
● Engine	0	3	4	1	0
● Structural	0	0	1	0	0
DESIGN	42	36	23	27	26

* Not mutually exclusive. All causal factors pertaining to a mishap are identified.

DEPARTMENT OF DEFENSE
AVIATION MISHAP EXPERIENCE

Examples of corrective actions as a result of mishap investigations or deficiency reports:

Aircraft Modification

- Wire Strike Protection System (WSPS).
- CH-47 Combining Transmission Dephasing Lockout
- HH-2 Main Gear Box Drive Shaft
- HH-53 Rotor Dampening System
- HH-53 Range Extension Tanks
- A-7 and F/FB-111 Flight Control Modification

Training

- OV-1D Formation Flying
- F-14 Carrier Launch Procedure for Loss of Engine
- Step-down Training in the Low Level Environment
- Ejection Decisions

Operational Procedures

- UH-1H Maintenance Manual
- Carrier Landings - LSO Informed of Aircraft Landing Configuration

Mr. **Glickman**. We thank you for your statement, as well as the statement of Dr. Kerrebrock. I would just raise a couple of questions, first with NASA.

All the witnesses to date have indicated the importance of NASA's work at Lewis, Ames, and Langley Centers, in connection with icing and other related things. Can you give us any idea about your budgets for the next fiscal year for these areas that you testified on today?

Dr. **Kerrebrock**. Yes, sir. The budget for R. & D., for fiscal year 1982 was about $17 million. We are expecting our fiscal year 1983 budget to be about $19 million.

Mr. **Glickman**. $17 million in 1982. That is for the safety-related issues——

Dr. **Kerrebrock**. Yes, sir, for safety related R. & D. including human factors as well as those areas you mentioned.

Mr. **Glickman** [continuing]. And then 1983 would be $19 million. What did you have in fiscal year 1981? Do you remember?

Dr. **Kerrebrock**. It's about $13 million.

Mr. **Glickman**. You are confident that you can continue the work in the areas that you have begun some years in the past?

Dr. **Kerrebrock**. Yes, sir, we placed a very high priority on this. They are mostly funded out of our R. & T. base.

Mr. **Glickman**. And these would include those agencies that you are doing work for, such as the FAA?

Dr. **Kerrebrock**. There is some additional funding transferred from FAA. I think it is about $4 million for the 720 crash tests and ASRS, for example, and some other cooperative research.

Mr. **Glickman**. With respect to the Aviation Safety Reporting System, this is something that I do not think very many people realize, that there is a basically nonregulatory receptacle for accidents and for problems in aviation reported by pilots. Captain O'Donnell makes reference to this in his remarks, in which he said that the tendency has been to view this as a kind of data collection system for almost historical purposes, as opposed to a system for planning future oriented activities, such as making sure that research is done in areas where there seems to be a lot of need for research.

I wonder if you might explain to this committee what in fact you do with the information you receive. As I understand, this is confidential information. Nobody has to sign their name to this information.

Dr. **Kerrebrock**. The basic design behind ASRS is to collect information on incidents, as opposed to accidents. That is, to have a format in which pilots, air traffic controllers, anyone involved in the air transportation business can volunteer information on near accidents or incidents and thereby develop a data base on the basic causes of air traffic accidents. It is a confidential data base, as it has to be, in order to get that kind of data input. The data is used in two ways: First, a single report is received which indicates the existence of a time critical problem. An "Alert Bulletin" is issued immediately to the organization that has cognizance over the problem and a copy is sent to the FAA. The second usage is to perform statistical research on the data base to ascertain the existence of trends which do not become obvious from single reports.

Mr. **Glickman**. Is all this information shared with FAA and DOD also, so they can analyze if there are any regulatory changes needed?

Dr. **Kerrebrock**. In the statistical form, it is. Information on the individual incidents is not shared but the statistical data are.

Mr. **Glickman**. Why is not information on specific incidents shared?

Dr. **Kerrebrock**. The feeling is that the individual incident is not particularly relevant; it is the overall conclusion that follows from a large data base which is important.

Mr. **Glickman**. Would that destroy the confidentiality, or not?

Dr. **Kerrebrock**. It would not destroy the confidentiality, because the basic ground rule is that the data will not be attributed to the source. The reports are "de-identified." That is, any information which could lead back to the person that made the report is removed.

Mr. **Glickman**. Are you doing any work in icing, in the area of the optimum glycol-water mix or substitutes for glycol as a deicing solution?

Dr. **Kerrebrock**. No; we are not. I should correct that by saying that we do have a small effort on what are called iceophobics, such as Mr. Siewert referred to. This is a material to which ice does not adhere, but we do not do any work on glycol or deicing.

Mr. **Glickman**. Do you have any knowledge of why there has not been any significant work done in the last several years into alternatives to the glycol-water mix? Is it that it is such a superior solution that there is no reason to do any additional work on it?

Dr. **Kerrebrock**. I have no real information on that subject.

Mr. **Glickman**. I would like to ask Mr. Siewert. We talked a lot about the crashworthiness of seats. Mr. Dunn, Mr. Walker, and I have all asked questions about the rationale of why, in so many military aircraft, seats are faced toward the rear as opposed toward the front. I wonder if you might comment on that?

Mr. **Siewert**. Mr. Chairman, I believe the rationale had to do with increased survivability in the event of crash. Unfortunately, we do not have any data to substantiate that with us. We can attempt to search the safety system to see if there are any data that indicate that rearward-facing seats are safer or more survivable than forward-facing seats.

Mr. **Glickman**. It sounds to me as if a commonsense decision was made about 30 or 35 years ago how to turn seats around.

Mr. **Siewert**. I believe you are right, sir. The Navy still uses rearward facing seats on all passenger carrying aircraft that operate from aircraft carriers.

Mr. **Glickman**. I would like you to search your records, if you would not mind, on that issue.

Mr. **Siewert**. We certainly will, sir.

[The information follows:]

AVIATION SAFETY RESEARCH

Mr. **Glickman**. Why in so many military aircraft, are the seats faced toward the rear as opposed to the front?

Answer: The Navy and Air Force have been installing rearward-facing aircraft passenger seats in their transport aircraft since the early 1950s. The decision to use rearward-facing seats was based upon acceleration research which showed quite convincingly that a person can tolerate much higher crash forces when facing to the rear. Also, during the 1940s and 1950s, the US Army Air Force, Royal Air Force, US Navy and the US Air Force studied propeller-driven aircraft mishap data and concluded that survivability was enhanced with the use of rearward-facing seats. Since the advent of the all-jet Air Force transport force, no new conclusions, based upon mishap data, have been drawn by Air Force on the rearward vs foreward-facing seat issue. The lack of aircraft with both types of seats, as well as the relatively small number of survivable aircraft crash mishaps which could be studied, has made this a difficult subject to analyze statistically. Even so, the preponderance of evidence and data favors the use of rearward-facing seats.

A very thorough review of this subject, one which parallels the US Air Force experience with passenger seats, has been prepared for the Aerospace Medical Panel of AGARD/NATO and is published in AGARDograph No. 221.

In addition, a comprehensive report entitled, "U.S. Navy Approach to Crashworthy Seating Systems," has recently been completed by Mr. Marv Schulman at the Naval Air Development Center, Warminster, PA. This report covers twenty-five years of development in crashworthy seating and is available if desired.

Mr. GLICKMAN. NASA has, for some years, asked for a proposed numerical aerodynamic simulator [NAS]. It has been a high priority of theirs. Are you aware of this?

Mr. SIEWERT. Yes, sir.

Mr. GLICKMAN. What is your general feeling about NAS with respect to a variety of R. & D. activities, particularly in the area of icing research maybe? Do you think that would be a valuable tool?

Mr. SIEWERT. It certainly would. There are two aspects, as I see it, of the icing research problem. One is to understand the whole phenomenon of icing so that we can model it accurately, using tools such as the NAS or other aerodynamic modeling concepts. I think it would be a valuable tool in that regard.

Mr. GLICKMAN. Mr. Dunn?

Mr. DUNN. Thank you, Mr. Chairman.

A question for Colonel Try. Talking about the first few seconds of a takeoff, an aircraft goes through V-1, which is virtually rotating speed, and V-2, which is the point when a go-no-go decision must be made. Part of that function of V-2 is length of runway left available to that aircraft, and whether or not you tuck the gear and go throttle-back. To solve that problem, the Air Force has made the decision that runway-marker and distances-left-to-go is a practical means to help the pilot in that decisionmaking process, while the FAA has decided not to incorporate these markers for commercial airports. I guess their rationale is that it is cost-prohibitive. Does the Air Force find that it is cost-prohibitive to install runway-distance markers?

Colonel TRY. I would like to pass that comment to Mr. Siewert, in that we are not discussing the operational aspect of it, and I am not an expert in the operational aspects of flight safety.

Mr. DUNN. You would agree that the Air Force has made the decision to put runway markers in?

Mr. SIEWERT. Yes, sir.

Mr. DUNN. And you would agree that they are not at commercial airports?

Mr. SIEWERT. No, sir, they are not.

Mr. DUNN. Is there any other reason than that the cost of signs might be expensive?

Mr. SIEWERT. I have no idea, sir. We represent the research community, and we had asked whether operational considerations would be discussed today. We were informed that they would not be, so we do not have the operational people here. If there are any questions along that line, we can certainly get the answer.

Mr. DUNN. I would appreciate knowing the rationale.

[The information follows:]

AVIATION SAFETY RESEARCH

Mr. DUNN. What is the rationale for the Air Force use of runway distance markers?

ANSWER: Distance markers were placed adjacent to Air Force runways during early 1950s to enhance pilot situational awareness during takeoff and landing phases of flight.

Markers were conceived as a logical and simple method to provide runway length information to pilots. Air Force recognized need to assist pilots in judging safe takeoff performance and landing deceleration characteristics based upon remaining runway length.

Addition of distance markers is historically linked to introduction of century series fighter aircraft (F-100) and heavy bomber-aircraft (B-47).

Little, if any, empirical data provided impetus for initial installation. New aircraft prompted new pilot aids.

Runway distance markers provide a margin of safety unique to the operational/performance characteristics of each aircraft.

Markers provide visual cues during landing which allow pilots to determine required deceleration/braking technique during instrument or night conditions.

Markers provide means for judging effectiveness of deceleration/braking techniques and need for alternate braking or arrestment considerations.

Markers allow comparison of computed takeoff distance with actual travelled distance and rotation/liftoff capability.

Markers assist in takeoff about decisions by corrolating position on runway with stopping distances required under various meteorological conditions.

All Air Force runway distance markers conform with regulatory standards of size, illumination and runway proximity. This yields safety benefit when landing on unfamiliar runways.

In summary, runway distance markers are vital in both maintaining awareness of the aircraft/runway relationship and in fostering prompt decisions concerning safe actions when abnormal circumstance arise.

Mr. DUNN. The second question is one Mr. Walker touched on. In your research endeavors, the auto industry spends a lot of money on crashworthiness certificates, and recognizing that there is a difference in impact forces on the human body in an automobile versus an airline, nevertheless the question was asked of FAA do they do any coordinated research, and the answer seemed to be no. So I will ask the same question of DOD. Have you taken any look at the research tests that the Big Three do on crash survivability? It would seem an excellent source on at least basic information.

Mr. SIEWERT. I would like Dr. Peters, from the Air Force Systems Command, to address that, if we may.

Dr. PETERS. We do have unique facilities for testing human impact, and we do indeed share those results with the National Highway Traffic Safety Administration, helping them to determine the safety of infant seats, et cetera. We have indeed provided them data in support of their efforts.

Mr. DUNN. I guess I was asking the other side of that. They are also conducting tests. Do you take a look at their tests results and use their information?

Dr. PETERS. I am not aware of that happening. I am more aware of us providing to them.

Mr. DUNN. I would suggest it might be a means——

Mr. **Siewert**. I might also ask Mr. Carper from the Army Applied Technology Laboratory at Fort Eustis. He is an expert in crashworthiness.

Mr. **Carper**. In the later sixties and early seventies, the Army put together a crash survival design guide, which was done with the aviation engineering and research organization with assistance from Arizona State. An initial part of the look-see in putting that design guide together was with the automotive industry. One of the first people that did the work for the Army in actually compiling the document was one who was instrumental in the automotive crashworthiness work. Since then, our primary interest is in helicopters. Loading conditions in helicopters are different from loading conditions in automobiles.

Mr. **Dunn**. Thank you.

Doctor, in your testimony you touched on cockpit display information. I mentioned this to the FAA once before, and I would like to go on record once again, that I have great reservations about any type of system cockpit display that would transfer primary responsibility for air traffic separation from the ground system as we know it today to an individual pilot decisionmaking process, and that seems to be, at least partially, what we are moving toward when we ask for complete cockpit display of traffic surrounding us.

I think we have to be very concerned about an air traffic controller on the ground who is monitoring up to 20 airplanes on one scope, and suddenly one of those nervous pilots decides that he is too close to somebody else and starts taking deviation actions that are not related to what the controller is doing on the ground.

So I approve of the research that is going on, but I think we should be very concerned about this question we have had for 50 years in aviation about who has ultimate control on aircraft separation. I would urge you in your research to consider that.

Thank you, Mr. Chairman.

Dr. **Kerrebrock**. Our research program is directed, to a considerable extent, to that very question, which is: "What part of the job should the pilot have or what part can he properly take over?" Our present view is that the ground control could certainly continue to have a strategic command of the situation; but, the pilot could contribute something to the local situation. Two are better than either alone, if properly managed.

Mr. **Dunn**. The first ATR he was talking about is simply a cockpit cabin alert system that there is traffic in front of you and action is taken to avoid that. No. 1, I would ask that this signal also be sent down to the controller so that he knows that one of these airplanes on the scope is taking an action. I see that as a first step, but there are steps going beyond that, in which all 20 aircraft surrounding my aircraft are undisplayed. If you get three or four guys making individual decisions to take corrective action, you could have serious problems.

Dr. **Kerrebrock**. Yes, sir, we agree. We are addressing that via simulation techniques.

Mr. **Dunn**. Thank you very much.

Mr. **Glickman**. Mr. Gore?

Mr. **Gore**. Thank you, Mr. Chairman.

Mr. Siewert, how much real dialog does DOD have with the FAA with respect to air safety research?

Mr. **SIEWERT**. That is a difficult question to answer, Mr. Chairman. We share a lot of common data, common programs. At the working level, I would say there is extensive dialog, but when we get into the design requirements for aircraft, we obviously procure and operate our own aircraft and have a different set of rules that we operate under than the FAA does in the regulatory world. We generally participate with technical people, assisting in reviewing proposed new regulations for the FAA rulemaking and that sort of thing, but there is no formal dialog to my knowledge. There may be a formal organization that is established, but I am not aware of it.

Mr. **GORE**. We heard testimony that the Army, at least, agreed with or was taking the same position as FAA on the uncertainty relating to whether or not the seat standards were currently at the upper limits of human G-force tolerability. Is that your understanding of it?

Mr. **SIEWERT**. No, sir, we have a firm requirement for helicopter crashworthiness. In essence, our requirement is that we shall not exceed 23 G's for 6 milliseconds. That is in the design guide which is published in five volumes and is available for anybody who is interested. The thing is, this will not result in an injury-free accident. There will be injury, but it will not be severe injury, and it will be survivable.

Mr. **GORE**. When you say helicopter, the same thing would apply to airplanes?

Mr. **SIEWERT**. At the present time, our fixed-wing aircraft are not designed to crashworthy standards or criteria.

Mr. **GORE**. Is it the view of the Department of Defense that the current standards for airplane seats allow the seats to withstand a force of G's significantly less than the force which the human body could withstand?

Mr. **SIEWERT**. I am afraid I am not the one to answer that, and I do not believe we have an expert on that particular subject, unless Mr. Carper from the Army might be able to.

Mr. **CARPER**. May I revert back to an earlier question relative to this?

Mr. **GORE**. Sure.

Mr. **CARPER**. There is an active interagency agreement in the specific area of structural crashworthiness with the Federal Aviation Administration and the Army. There are active programs. For about the last 2 years, the Civil Air Medical Institute at Oklahoma City, as part of establishing human tolerance limitations, has conducted between 30 and 40 dynamic sled tests specifically for the Army. So there is a fair amount of exchange between the Army and the FAA in this area.

On the other issue, the Army has a military standard relative to the design of a crew seat: Mil S. 58095. That does call for designing to and testing to G-levels which are considerably higher than those we talked about earlier relative to commercial seats.

Mr. **GORE**. So the Army's view would be that the current seat standards, at least as they compare with the standards you just cited, are deficient?

Mr. CARPER. I have to get back to the total system aspect of designing for crashworthiness. The seat standard itself is only one part of that aspect. We feel that seats, yes, could take more of the load and protect the occupant in the seat at higher loads than 9 G's.

Mr. GORE. That is a critical point, and I appreciate that. Earlier the FAA had been criticized by the NTSB as being isolated in its position that this is an uncertain question, and they turned to the Army to buttress their position. Evidently the Army does not really buttress their position, at least insofar as it is isolated to the question of the seats.

To put a point on that, we do not need a lot more research—evidently, most people agree—to determine whether or not the seats can be improved. They can be improved, and it will do a lot of good, because the human body can withstand more than what the current seats will allow the human body to withstand. So we need to move much faster there and not try to answer a question that has already been answered.

Mr. Siewert, when do you expect that your computer model will be able to successfully simulate ice formation on airfoils?

Mr. SIEWERT. We have no projection for that, Mr. Chairman. We have to do significantly more work in the basic physics of the icing phenomenon before we feel we can accurately model it and use it as a design tool. Work is progressing, but we do not have an answer or projection at this time.

Mr. GORE. I am told that there are three kinds of ice. You get the rime ice, sheet ice, and clear ice. Are you close for any of the three?

Mr. SIEWERT. The model was designed to handle both the clear ice and the rime ice. It has successfully been validated for curved objects, but when we get into the flow fields of airfoils, the physics is still too complicated to model.

Mr. GORE. Does DOD coordinate and communicate aviation safety results with other Government agencies?

Mr. SIEWERT. With regard to the research programs that I discussed in my statement, yes, we do, by a number of different mechanisms. Obviously, we report all this information out in technical reports. Second, as Mr. Carper indicated, we have several joint programs ongoing with FAA and with NASA in areas of concern for safety. Obviously, our specifications that our airplanes must be designed to, such as the flying qualities specification I referred to in my remarks are available as unclassified documents for the industry and anyone else who is interested in reading them.

Mr. GORE. Just in closing, I want to thank all of you for the hard work you do on a regular basis in this area. You can see, in the results of the tragedy, how much the Nation relies on the work that you do. Thank you for that work.

Mr. SIEWERT. Thank you, Mr. Chairman.

Mr. GLICKMAN. I would just ask one final question, Mr. Siewert. Has the Department of Defense developed a small, lightweight voice and flight data recorder applicable to general aviation?

Mr. SIEWERT. I do not know whether it is applicable to general aviation. We have just now started putting flight data recorders in the F/A-18. This is the first aircraft the Department of Defense will have flight data recorders in. It is a digital system, all solid state, but I will have to get more of the details on that; I do not have them available.

Mr. Glickman. Did you have an additional comment, Mr. Carper, on that?

Mr. Siewert. Mr. Carper has a different program in the Army that is broader-based than a flight data recorder.

Mr. Carper. We recently developed and tested what we refer to as an accident information retrieval system. It is a system that will give you both flight data and aircraft crash or accident data. It is an all-solid-state system. By itself, it has a microcomputer on board, and it compresses the data. For example, we have flown it on the Black Hawk aircraft in breadboard form, and at a 10:1 data compression, sampling only one-tenth of the time. We duplicated data plots obtained with a fully-instrumented aircraft.

The crash data recorder portion of it is designed to give you initial impact conditions—that is, magnitude, direction, duration—of initial crash forces, plus it is designed to continue to work 5 seconds after crash to give you secondary crash forces. It is extremely difficult to get a flight data recorder on an Army aircraft, so we are in the process now of trying to combine that with other functions, such as condition monitoring and diagnostics on the aircraft, where we can go beyond scheduled maintenance and removal of parts and go with an on-condition removal of parts. So that is being referred to as a flight and maintenance information system.

Mr. Glickman. Do you have any cost estimates on these yet?

Mr. Carper. On the accident information retrieval portion of it, the basic unit, in a weight sense, would be about 7½ pounds, with about another 7 or 8 pounds for installation. So we are talking about 15 pounds. The cost would be in the neighborhood of $10,000. I am sorry I do not have costs on the combined unit that would put the flight-data/crash-data in conjunction with maintenance data, but I can get that for you if you would like to have it.

Mr. Glickman. Are you sharing this information with the FAA?

Mr. Carper. Yes, sir. FAA and NTSB both are interested, and the Air Force and the Navy also.

Mr. Glickman. And general aviation people, I wonder if they are involved at all: manufacturers or users?

Mr. Carper. In the context that the FAA and the NTSB are involved, yes, sir, but I cannot answer directly whether there has been direct contact with Cessna, Beech, or those companies.

Mr. Glickman. Thank you. Again, I would like to echo what Mr. Gore said. We appreciate your work and your testimony very much.

Mr. Glickman. Our next witnesses are Capt. J. J. O'Donnell, president of the Air Line Pilots Association, and John E. Ralph, senior vice president of the Air Transport Association of America.

I might ask if Mr. Joseph Stiley has come into the room as yet or anybody representing him?

[No response.]

Both of you gentlemen here are well known to the aviation community, and your thoughts on aviation safety are very important. Again, as both Mr. Gore and I have said, your entire statement will appear in the record, so you may feel free to summarize if you wish. We will begin with Captain O'Donnell.

STATEMENT OF CAPT. J. J. O'DONNELL, PRESIDENT, AIR LINE PILOTS ASSOCIATION; ACCOMPANIED BY JOHN O'BRIEN, MANAGER OF ENGINEERING AND OPERATIONS, ENGINEERING AIR SAFETY DEPARTMENT, AIR LINE PILOTS ASSOCIATION

Captain O'DONNELL. I have with me Mr. John O'Brien. He is the manager of engineering and operations in the Air Line Pilots Association's Engineering and Air Safety Department. As you said, our statement will be in the record, but I would like to make several statements.

First, we are a direct participant in the NTSB investigation of the Air Florida crash, and we are also seeking to have the NTSB schedule hearings on the World Airways DC-10 accident in Boston. Listening to the questions since the hearing started this morning, I note that many of the questions are getting into areas that may flow into those two accidents. We are respectfully requesting that when that point does come, we may want to request that we have our position respected with regard to not commenting on matters that would touch on those two accidents.

I would also like to say that the points we are raising here that concern us have to do mostly with issues that we have testified to before Congress, to my personal knowledge, for the last 11 years. On numerous occasions we have also testified before the FAA.

These points have to do principally with our continuing concern over low-visibility approaches and visual cues that pilots are required to use to establish a landing. I think overrun excursions on runways are a long-term problem the airline pilots have had. We are concerned about the runway and taxiway lighting we have available today for the current minimums we fly into but also with the fact that substantially lower minimums in the next few years are being considered. Our runway friction measurement problem is something that is 10 to 12 years old, again from my own personal knowledge. The ASRS program is, I think, a vital tool that is not getting the attention it should. I think these hearings may add some impetus to that.

The last and perhaps most important area that we will touch on is human factors research. I think an awful lot has gone on with that in the past, but the information is not being used properly, so the people who operate the system can get some benefit out of it. I think there are accidents occurring right now and will occur in the future that, had we gone into an aggressive human factors program a decade ago or two decades ago, perhaps we could have prevented some of the accidents that are occurring today.

We hope that the actions of this committee will not die here, as they have in past Congresses. We hope that you aggressively pursue the FAA and NTSB, the airlines and the industry, to not sit back. I think it is time that the Congress and everybody else involved in aviation to step up and say, "The honeymoon is over. Now let's do something about all the data we have. Let's establish deadlines for research to be completed."

I have heard some questions that are very well put. These have to do with these new twin-engine aircraft and bird ingestion, which I think are very important. We have forgotten the lessons of the past, and I am afraid that unless you gentlemen do take an aggressive position, we are going to relive those same accidents in the future.

Thank you very much, Mr. Chairman. We will answer whatever questions we can.

[The prepared statement of Captain O'Donnell follows:]

STATEMENT OF
CAPTAIN JOHN J. O'DONNELL, PRESIDENT
AIR LINE PILOTS ASSOCIATION
BEFORE THE
SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT
AND THE
SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS
COMMITTEE ON SCIENCE AND TECHNOLOGY
U. S. HOUSE OF REPRESENTATIVES
MARCH 9, 1982
AVIATION SAFETY RESEARCH

Good morning, Mister Chairmen, and members of the Subcommittees. I am Captain John O'Donnell, President of the Air Line Pilots Association. With me today are Captain John J. Ruddy, an active airline pilot with much experience in aviation safety, and John O'Brien, Manager of Engineering and Operations in our Engineering and Air Safety Department.

On behalf of the 33,000 members of ALPA who fly for 36 airlines, we are pleased to have this opportunity to present our views on current needs in aviation safety research. Your letter inviting us to testify mentioned a variety of topics that are the subject of current research by both the federal government and private organizations. In the interests both of emphasis and brevity, we would like to limit our testimony today to those areas where we believe the need for more research and effort is greatest.

In doing so, we have no intention of downplaying the importance of subjects we do not mention. Clearly, such topics as cabin interior flammibility and toxicity, wind shear and weather merit further research. This research is going on today. I also wish to point out that ALPA has extensive supporting documentation on both the topics we will discuss here and the others mentioned in your letter. We will be glad to make this material available to the Subcommittee members and staff if you wish.

The topics we will discuss are not new ones in aviation safety. It is a truism in aviation safety today that there are no truly new problems; rather, old problems keep resurfacing in new manifestations and combinations. The five topics we will address today are:

* The Aviation Safety Reporting System (ASRS). We believe it has been underused as a guide to areas deserving emphasis in research.

* Runway Friction Measurement. We have not attained the goal of being able to give the pilot accurate, timely information about the condition of the runway.

* Runway Markings. Further improvements are needed to assure the pilot knows precisely where the runway is during landing in bad weather and where he is on the runway during takeoff.

* Low-Visibility Surface Guidance. It is legal for a pilot to taxi when the visibility is zero even though current taxiway markings are inadequate. More attention also needs to be given to determining and allowing for slant visual range as well as runway visual range.

* Human Factors. This topic covers a vast variety of subjects dealing with human performance, decision-making and reaction, why human errors are made, and how to prevent them.

Aviation Safety Reporting System

The ASRS was established in 1975 by the Federal Aviation Administration and the National Aeronautics and Space Administration to acquire information about possible deficiencies and discrepancies in the national aviation system. At that time NASA determined that participation in ASRS would "significantly increase" its ability to fulfill its aviation research and development responsibilities.

As the Subcommittees are aware, the FAA tried to abolish the ASRS program in 1979. Only the outcry from the entire aviation community and the opposition of Congress dissuaded the agency from ending ASRS. Instead, it was revised. According to the revised Memorandum of Agreement between NASA and the FAA, ASRS "will be designed primarily to provide information to the FAA and the aviation community to assist the FAA in reaching its goal of eliminating unsafe conditions and preventing avoidable accidents."

ALPA has supported ASRS since its inception, and we constantly encourage our members to report unsafe incidents and conditions to ASRS. As a result of reporting by ALPA members and many others in the aviation community over the years, a sizable base of data about actual operations in the system has been built up.

Now, we believe, it is time to do specific research with this large data base and thus determine what are the current and potential problems in our aviation system. To date, the ASRS data base has been used almost entirely to study events that took place months ago. While informative and useful, such activity is not an adequate guide to the future. In other words, we should use ASRS more to look into the future, detect problem areas and guide research and development toward devising solutions before these problems become serious.

Runway Friction Measurement

How to determine aircraft performance on a runway contaminated by rubber or fuel deposits or covered in water, slush, snow or ice is a long-standing problem in aviation safety. The current winter weather and some recent accidents where the condition of the runway was a factor have highlighted this problem.

Today, after years of effort, we appear to have reliable methods of using ground vehicles to measure runway friction. What still remains to be done is to correlate the measurements from the ground vehicles with actual aircraft performance. That task is made more difficult by the fact that different aircraft will perform differently under the same runway conditions.

An ALPA consultant has developed a theoretical method of doing this correlation between friction measurement and aircraft performance. This method was well received at a technical conference last November in Seattle. What needs to be done now is to have the FAA or NASA test this theoretical method to determine if it works in the real day-to-day world of airline operations.

The FAA and NASA's Langley Research Center are continuing other work in this area. The two are developing a ground handling simulator that will be used to evaluate alternative pilot braking techniques. They are also exploring using this simulator to evaluate various pilot braking techniques.

Runway Markings

Another aspect of the runway that needs additional research is the markings. We believe more research is needed in runway lighting and marking to provide better guidance to the pilot during low-visibility approaches. Specifically, there is a need for better lighting to mark the runway threshold and for chevron markings and flashing lights to indicate more clearly to the pilot where the runway centerline is.

The major improvement in runway markings that we advocate is the installation of distance-to-go runway markers. These are boards set along the side of the runway at 1,000-foot intervals to show the pilot how much of the runway remains. They would be very useful in indicating actual aircraft performance on the runway during takeoff or landing and would also assist the pilot at those times when the runway surface markings were obscured.

The Air Force already has these markers installed on its runways. In 1975, we petitioned the FAA to require these markers on all air carrier runways. Two years later, the agency rejected our petition, saying that the cost of installation and maintenance of these markers outweighed the "limited benefits" expected. We think it is appropriate for the FAA to take another look at runway distance-to-go markers.

Low-Visibility Surface Guidance

A related area where more research is needed involves guidance to pilots on the surface during conditions of very low visibility. Preparations are under way to allow aircraft to land under Category III B or C Instrument Flight Rules, where the runway visual range (RVR) is less than 700 feet and may be as low as zero. As I mentioned earlier, improved lighting systems will be needed in guiding the pilot to the proper place on the runway. Better runway and taxiway marking systems will also be needed to guide the aircraft to the terminal once it is on the ground. It does little to increase airport efficiency if an aircraft can land in zero/zero conditions and then has to wait to be towed into the terminal because of a lack of taxi guidance on the runway, taxiways and aprons.

There is general recognition both within the airline industry and the federal government that more research in ground guidance will be needed before we will be able to take full advantage of the improvements attained in instrument landing systems.

Currently, after landing in zero visibility, the pilot has no way of knowing where he touched down on the runway and no indication of aircraft stopping performance. In short, he doesn't know if he will be able to stop before the end of the runway. ALPA believes more research is needed, and that such research would involve runway friction measurement, runway markings and low-visibility surface guidance. Specifically, we believe the FAA or NASA should determine whether a cockpit instrument is needed to show aircraft stopping performance. If so, further research will be needed to develop such an instrument.

Human Factors

The last of the five topics is human factors. It is probably the most important subject to be discussed in this hearing. It is certainly the most encompassing.

ALPA has been concerned for many years about the relative lack of attention paid to human factors research. This situation is particularly disturbing in view of the fact that human factors are involved in the majority of aviation accidents -- anywhere from 60 to 90 per cent of all accidents, according to various studies.

Airline aircraft today are extremely reliable, and most accidents do not involve an equipment failure. Thus, the cause of the accident is usually attributed to "pilot error, " that is, the pilot didn't do something he should have or did something he should not have. Such a superficial finding, however, overlooks the obvious: pilots are not suicidal and do not deliberately set out to jeopardize their passengers or themselves.

Therefore, we need to go beyond the mere finding of "pilot error" and determine why the error was made. In most accidents, it is not just one element but a combination of factors in a complex sequence that led to the accident. That situation, of course, makes it more difficult for accident investigators to pin down all the underlying causes that contributed to pilot error.

An excellent example of the difficulties in determining the underlying causes of accidents involving human error is the worst airline accident of all time -- the March 1977 collision of two Boeing 747s on the runway at Tenerife in the Canary Islands. ALPA did its own study of the human factors in this accident, and we would be glad to make that report available to you if you wish.

We also see a tendency today in aviation to devise equipment that will help prevent human errors without making any real effort to understand what factors are causing the errors. That is treating the symptoms but not the causes.

A good historical example involves controlled flight into terrain (CFIT), where an aircraft hit the ground due to pilot error. After repeated recommendations from the National Transportation Safety Board in the late 1960s and the early 1970s, the FAA required all airline aircraft to have a ground proximity warning system (GPWS). This system has been quite successful in reducing the number of CFIT accidents, but it has done nothing to address the underlying problem: why do such deviations occur?

Today, a great deal of attention is being paid to automating the airline cockpit with the worthy goals of reducing pilot workload and the possibility of human error. The premise that automation per se is a good and safe way to proceed has become prevalent. However, a NASA/industry workshop in July of 1980 on "Human Factors of Flight-Deck Automation" identified a number of issues that need further research before we make a greater commitment to automation. These issues include monitoring of systems, transfer of information and integration of automatic functions.

A very basic question in cockpit automation that remains unanswered is: How much information does the pilot need to adequately assess the performance of automatic systems? We pilots -- who are charged with the ultimate responsibility for the safety of our passengers -- strongly believe we must have sufficient information to determine ourselves if the automatic systems are truly functioning as they are supposed to.

An earlier NASA workshop in the summer of 1979 dealt with resource management in the cockpit and featured extensive discussion of such problems as crew coordination and communication and different aspects of pilot training. As a result of this workshop, some airlines have established cockpit resource management programs of their own. However, not all carriers have done so, and we therefore see a need for a central focal point to stimulate more research and to encourage other airlines to adopt similar programs.

Unfortunately, the FAA has not moved as forcefully as NASA. We were disappointed in the human factors workshops the FAA held in 1980 and 1981 because they were shallow and not well focused. Even more disturbing is the fact that the agency has done very little in the human factors area since these workshops.

Other areas of human factors research that we believe merit greater attention from NASA and the FAA include the decision-making processes in the cockpit and the effects of outside pressures on pilots. These subtle pressures include such things as the desire to get home, and the desire to win the approval of one's peers. Some pilots might be more inclined to break off an approach and go to an alternate airport instead of trying to land on a short, slippery runway in minimal weather if they knew (1) that other pilots were doing the same thing and (2) they would not be called in to explain to the airline management why they cost the company money by diverting.

These areas are just a few of the many facets in the complex field of human factors that need additional research. Again, as I mentioned earlier, the extensive data base in the ASRS should be exploited more to provide the raw information in such research and to suggest areas where such research would be most effective.

That concludes our prepared testimony. We thank you for this opportunity to describe to the Subcommittees those areas in aviation that most need additional research. We will be glad to respond to any questions you may have about our testimony.

Mr. GLICKMAN. Thank you, Captain O'Donnell.

General Ralph, we are glad to have you here. You may proceed.

STATEMENT OF GEN. JOHN E. RALPH, SENIOR VICE PRESIDENT, OPERATIONS AND AIRPORTS, AIR TRANSPORT ASSOCIATION OF AMERICA

General RALPH. Mr. Chairman, in view of the fact that my statement has been admitted to the record, I will confine my remarks to a few items which I believe are worthy of our attention in this hearing.

Let me first start by pointing out that this Nation's air transportation system is the safest and the most advanced form of public transportation in the world, and we shall take every action necessary to keep it that way.

I believe it is important to recognize that research and development has contributed significantly to the improvment in flying safety over the years. Research in aerodynamics and aeroelasticity has given us airplanes of greater efficiency and greater safety in their flight characteristics. Turbojet engines and solid state electronics are specific examples where more reliable systems have contributed to the outstanding safety record of the airlines.

In our view, it is very important for the Government to continue to fund research and development so that continuing improvements in efficiency and safety can be realized. I would like to draw to your attention three areas of concern with respect to Government funding of research and development regarding NASA and FAA programs.

First, when it comes to aviation safety and efficiency, we do not agree that basic research should be Government and developmental research should be private. We do not believe there is a natural break in knowledge that corresponds to these human-defined categories. To the contrary, such classification could lead to a premature termination of developments, short of needed demonstrations to verify that the development is worthy of implementation.

A good example exists in the case of the advanced turboprop fan propeller. There are still aerodynamic and aeroelastic problems with highly swept propeller blades that need to be resolved through research. In addition, fundamental challenges exist in the gear boxes and hubs that are required to transmit the high horsepowers envisioned. Thus, the technological unknowns of the advanced turboprop fan propulsion system spans the spectrum of basic and fundamental research categories. If the Government program is terminated now, it is unlikely that the aerospace industry would be in a position to carry on the research.

Our second concern is that Public Law 97-101, which included $284 million for NASA aeronautical research for fiscal year 1982. This was curtailed to $233 million without consultation with Congress or the industry. This reduction in programs in fiscal year 1982 appears to be an attempt to force congressional actions on the fiscal year 1983 budget, without an opportunity for adequate deliberation on the issues.

The third area of concern is with respect to the FAA. The final fiscal year 1982 research and development appropriations came in at a level far below that discussed during public testimony. This curtailment has reduced FAA research and development to such a low level that the FAA efforts are at a virtual standstill.

I would ad lib here. I believe that Mr. Albrecht essentially confirmed my statement. He acknowledged the reduced budget. We might argue with the adjectives and the adverbs that are used to modify nouns and verbs, but I think that we must recognize that Mr. Albrecht's polite style indicates that he is not only a scientist of some repute but is also a diplomat.

The projected furlough program will further complicate the FAA research and development programs. Together, these will cause major slippages in vital programs. We are concerned that the fiscal year 1983 budget request for the FAA research engineering and development and facilities engineering and development may not be sufficient to correct funding deficiencies of the past.

In closing, let me emphasize that both NASA and FAA research efforts need to be funded at a viable level, and their research and development programs must have some continuity and predictability and not be subject to stops and starts year in and year out. Programs such as NASA's advanced turboprop fan and FAA's ATC computer replacement program once initiated by the Government should be funded to a reasonable conclusion.

The safety records show an impressive improvement in airline operations over time, due to a great extent in our view to past research and development efforts. While major safety improvements may be more difficult to attain in the future, it is nevertheless vitally important that the Government continue to support research and development in a responsible and continuous manner.

Thank you.

[The prepared statement of John E. Ralph follows:]

Statement of John E. Ralph
Senior Vice President - Operations and Airports
Air Transport Association of America before
The House Committee on Science and Technology,
Subcommittee on Transportation, Aviation and Materials and
Subcommittee on Investigations and Oversight

March 9, 1982

My name is John E. Ralph. I am Senior Vice President, Operations and Airports of the Air Transport Association of America which represents virtually all of the nation's scheduled air carriers. It is a pleasure to be here today to offer our views on the important subject of research and development and air safety matters.

This nation's air transport system is widely recognized as the safest and most advanced form of public transportation in the world. We shall take every action necessary to keep it that way.

The airlines take most seriously their legal and moral responsibility to give safety the highest priority. The growth of air transportation has depended above all else on the fulfillment of these responsibilities. Airline safety and reliability have improved substantially over the years, while major advances were accomplished in terms of the number of people carried and quality of service offered. An excellent example was the introduction of transoceanic jet service. Over the past 30 years, no matter how it is measured, the safety record of scheduled airlines has improved dramatically. For example, as noted in the following statistics of the National Transportation Safety Board:

U. S. SCHEDULED DOMESTIC AND INTERNATIONAL PASSENGER SERVICE

	Fatal Accidents per Million Aircraft Miles	Passenger Fatalities per Million Aircraft Miles	Fatal Accidents per 100,000 Aircraft Departures
1951-55	0.012	0.201	0.253
1956-60	0.008	0.195	0.197
1961-65	0.006	0.148	0.160
1966-70	0.003	0.073	0.134
1971-75	0.003	0.094	0.114
1976-80	0.001	0.056	0.091

A number of actions have had a major influence on this safety record. I shall not name them all, but a few examples are in order. Certainly the new facilities in the National Aviation System and continued emphasis on training of air crews and air traffic controllers have had a major influence. Insistence upon the highest possible maintenance standards, and continued aircraft and other hardware improvements have contributed. These actions are all related in some degree to fundamental research and development (R&D) efforts. Much of the aircraft improvement was, and still is, based on the early work conducted by the National Advisory Committee on Aeronautics (NACA). The aeronautical research and technology work of NASA continues to contribute significantly. Mechanical and structural reliability of aircraft systems has been increased as a result of improved engineering and development, both by industry and Government. Turbine engines and solid state electronics development are examples where more reliable systems have contributed to the outstanding safety record of the airlines.

While today's aircraft are mechanical marvels, there will always be the goal of improvement. Real needs exist today for technological improvements. Research and development must be pursued aggressively now and in the future to achieve continuing gains. Times are changing and new areas of potential improvement need to be emphasized such as fuel conservation and increased Air Traffic Control system capacity, including reduced delays. More attention needs to be devoted to the human factors engineering part of the equation.

In our view, much of the needed R&D effort must be conducted by the Government, not only for Government operated portions of the National Airspace System, but also so that results of this research will not be confined to one segment of industry but available to all U. S. industry and Government. The alternative of private development could be prohibitively expensive, and if undertaken could result in a large part of advanced technology being proprietary to one or a few corporations and hence not generally available to all producers. Extensive Government research resources available at NASA and FAA facilities should be utilized and not duplicated by private industry.

General Concerns About Government Support of R&D

In times such as the present, when there is a need to reduce Government expenditures, we see cuts being taken or proposed in research and development funds. In our opinion, this is due, in part, to the lack of visible and measurable short-term consequences of the proposed program reduction. However, in our view, these shortsighted cuts will result in difficulties a few years later.

We respectively wish to point out three general areas of concern with respect to Government funding of R&D, specifically regarding NASA and FAA programs.

First, when it comes to aviation safety and efficiency, we do not agree that basic research should be Government, and developmental research should be private. This philosophy would imply that there is a natural break in knowledge and programs between basic and developmental research. To the contrary, the categorization of research in this way appears to create an unnatural chasm in the spectrum of knowledge. This gap is particularly apparent in high technology endeavors, and carries the risk of prematurely terminating worthwhile developments, just short of the conceptual demonstration needed to establish the development as worthy of implementation. For example, such termination of Government effort does not appear to be in the public interest in the programs for the energy efficient engine and energy efficient transport, including advance turboprop, where the results should be available to all potential producers and not be proprietary to a single firm. With regard to the advanced turboprop, we are disappointed about the Administration's plans to cancel this effort as "developmental research," and believe the plans serve as an illustration of the unnatural categorization philosophy. There are still aerodynamic and aeroelastic problems with highly swept propeller blades, and fundamental challenges exist in design of gear boxes, hubs, and blades for the high horsepower required. While other aspects of an advanced turboprop may be sufficiently mature for industry to start development, solutions to these problems are needed. Thus the knowledge about advanced turboprops spans the spectrum of basic and developmental categories. Further, if terminated now, it is unlikely that industry can overcome the risk of developing such a contribution to fuel efficiency.

Second, we are concerned that the previous FY-1982 actions relative to NASA's appropriation seem particularly paradoxical. The FY-1982 program decisions have now been confirmed in the FY-1983 budget submission. Even though Public Law 97-101 appropriated funds including $284 million for NASA aeronautical research and technology in FY-1982, the Administration has stated it expects to spend only $233 million for aeronautics, a cut taken without consultation with Congress or industry. By decimating needed programs in FY-1982, there appears to be an attempt to force Congressional actions on the FY-1983 budget before Congress has an opportunity to deliberate on the issues. While these are times of budget austerity, we do not believe that the proposed cuts to the NASA budget are fiscally sound in the long run and are not in the best interest of the nation.

The third area of concern is with respect to the FAA. Here the situation is somewhat different. The FY-1982 FAA research and development appropriation adopted by Congress reflected a radical cut from the initially proposed budget, to levels far below any discussed during public testimony. Even with the now proposed supplemental, this curtailment has reduced FAA R&D to such a low level that FAA efforts are at a virtual standstill. The projected application of selective furloughs at FAA to reduce 1982 outlays will further complicate the situation. Together, these will cause major slippages on vital programs. Further, when compared with the original FY-1982 budget request of $118.5 million ($95.0 million for R, E&D plus $23.5 million for F, E&D), the FY-1983 budget request of $133.5 million to cover both R, E&D and F, E&D projects does not appear sufficient to correct the FY-1982 funding deficiencies.

Although a different subject, we must again object about the use of Aviation Trust Fund moneys for regulatory projects and for other such items contained in the F, E&D program accounts. These are clearly inherent duties of the Government in the exercise of its police powers in the public interest, and as such should be paid for from the General Fund of the Treasury.

Specific Programs

We understand the Administration's FY-1983 budget proposes to fund, to some degree, a number of safety- and efficiency-related projects in NASA and FAA including:

- Human Factors Engineering (NASA)
- Low Speed Systems Technology (NASA)*
- High Speed Systems Technology (NASA)*
- Commercial Aircraft Fuel Savings Program (NASA)
- Wake Vortex Alleviation Investigation (NASA)
- Air Traffic Control Development (FAA)
- Advance ATC Computer Development (FAA)
- Navigation Development (FAA)
- NEXRAD - Improved Weather Radar (FAA - Joint SPO)
- Aviation Medicine (FAA)
- Aircraft Safety
  - Lights and Markings (FAA)
  - Anti-Misting Fuel (Joint NASA and FAA)
  - Cabin Materials (Joint NASA and FAA)
  - Seats (Joint NASA and FAA)
  - Math Models (Joint NASA and FAA)
  - Aircraft Icing Study (Joint NASA and FAA)
  - Snow and Ice Control Techniques (FAA)
  - Lightning Strikes (NASA)
  - Improved Tires/Runway Interface (NASA)
  - Advanced Anti-Skid Systems (NASA)
  - Better Fire Extinguishments (NASA)
  - Characterization of Atmospheric Hazards and Effects on Aircraft (NASA)
  - Lateral Gust Gradient (NASA)

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* *Congressional consideration of funding reduction of programs marked with asterisk appears appropriate.*

There are a number of additional NASA and FAA programs which the Administration is unwilling to fund that the airlines believe should be pursued aggressively. These include such items as:

NASA

- Energy Efficient Engine
- Energy Efficient Transport and Advanced Turboprop
- Large Composite Primary Aircraft Structures
- Accelerated Wake Vortex Alleviation Efforts
- Advance Head-Down Cockpit Display Comparative Evaluation
- Turbine Engine Hot Section Technology
- Accelerated Development of Data Base on Lightning Strikes
- Velocity Acceleration Heading and Altitude (VGH) Studies - Including Application to Provide Flight Technical Error Data for Use in Program to Reduce Vertical Separation
- Numerical Aerodynamic Simulator

FAA

- Mode S - Automated Traffic Advisory and Resolution System (Using ground equipment at Mode-S sensors.)
- R&D for 1,000 Feet Vertical Separation
- Acceleration of Wake Vortex Detection R&D
- Acceleration of Development of Means to Provide Controller with Aircraft/Vehicle Identity to Enhance Ground Surveillance Radar
- Low Level Wind Shear - Development and Evaluation of Ground and Airborne Alerting Systems
- Acceleration of Demonstration of Full Microwave Landing System (MLS) Capabilities in Civil Wide Body Transport

- Development of Alternative Anti-Misting Additives for Jet Fuel (In cooperation with NASA.)

In recognition of the need for budget savings, we reluctantly agree that some programs will need to be cut. Accordingly, we believe the Cockpit Display of Traffic Information (CDTI) program is of lower priority and should be reduced in scope or eliminated before those listed above. Under these circumstances, while it will probably be necessary to trim the Terminal Configured Vehicle program, we suggest consideration be given to retaining some of the facilities in the NASA inventory for selected applications. In addition, care should be exercised that the head-up display work being conducted jointly by NASA and FAA not take on the appearance of a sales pitch, but rather concentrate on improving head-up displays, and fairly evaluating their disadvantages and advantages.

We also consider that a high level of human factors engineering capability has been demonstrated at NASA's Ames Research Center, and that suggested programs to duplicate this capability at other Government facilities should be turned down unless there is convincing evidence that NASA is incapable of satisfying the requirement. It should be noted that FAA has extensive background in air traffic control which should be useful in human factors engineering for the controller and the automated Air Traffic Control system. In addition, the Aviation Safety Reporting System operated by NASA and funded by FAA provides a unique and vital data base for pilot and controller human factors; the program should continue to be operated by NASA with funding provided by either FAA or NASA.

It should also be noted that the proposed new ATC computer system promises a number of features such as improved availablity/reliability and automatic conflict free clearances. These capabilities should inherently increase safety. Continuing research and development funding for this program is of vital importance.

We are concerned, however, that a key ingredient to this new and improved system is being ignored. I refer to the lack of clear-cut statements of intent by FAA to require Mode S transponders in all aircraft. Such a requirement would help assure that the ATC system is provided with information needed to operate efficiently and safely. We see little to be gained by developing a sophisticated technical computer capability without the follow-on implementation to provide necessary inputs.

Continued acquisition of certain products of FAA R&D is also appropriate. For example, we believe that solid state Instrument Landing System (ILS) equipment should be installed to replace obsolete tube-type systems used at airports, which will remain after the conclusion of the Administration's ILS procurement program. These solid state systems utilize improved antennas and other advanced technologies developed in previous R, E&D programs. Clearly, procurement of these systems should continue.

We support FAA plans in FY-1983 to implement an improved airport surface radar, the ASDE-3, developed some time ago. We also support near-term improvements to the ATC system by providing improved tools to the controller, such as the Electronic Tabular Display System (ETABS) and Automated Metering and Spacing. In addition, new controller trainees should be introduced to new control concepts as soon as practicable during their training, so as to develop a receptiveness to the likely future changes.

Funding Commitment Needed

Finally, we believe Government research and development programs need to have some continuity and not be subject to vagaries from year to year. Programs such as NASA's Advanced Turboprop and FAA's Computer Replacement program, once initiated by the Government, should be funded to a reasonable conclusion. Consideration of a multi-year authorization for research and development in both NASA and FAA may be warranted to insure this objective. FAA's permanent authorization for procurement and implementation of airways equipment has served well in the past, and need not be adjusted at this time.

Summary

In summary, the record shows an overall improvement in airline safety, due to a great extent, in our view, to past research and development efforts, as well as airline, airways and airport improvements. While future major safety improvements may be more difficult to attain, we recommend the continued funding of the specific projects I have identified.

This completes my prepared statement, and I will endeavor to answer any questions you or the Committee may have.

Mr. **Gore.** Thank you both very much. I want to underscore that statement which provoked you to ad lib. On page 6, you say,

"Even with the now proposed supplemental, this curtailment has reduced FAA R. & D. to such a low level that FAA efforts are at a virtual standstill." That is quite a statement, particularly in the wake of the tragedies.

Captain O'Donnell, let me shift the subject and ask you about a specific safety improvement that could be made. In your prepared testimony, you say, "We have not attained the goal of being able to give the pilot accurate timely information about the condition of the runway." Do you think that the SAAB friction tester is an advance in that direction?

Captain **O'Donnell.** We believe it is an advance in that direction, but we also believe there has been additional research done by NASA that really has not been pushed out in the forefront along with SAAB. The gentlemen mentioned in our statement, a consultant at ALPA, worked with NASA on this problem for over 25 years. We had the benefit of that background in our statement. There is a tremendous amount of research completed. We think it is close enough where a little expedited additional research would produce the type of measurement equipment we are talking about.

Mr. **Gore.** Your consultant was the man who worked out of NASA; is that correct?

Captain **O'Donnell.** That is correct—for 25 years.

Mr. **Gore.** And he developed the correlation between friction measurement and aircraft performance. You say that this method he used was well received at a technical conference last November in Seattle, and what is needed now is to have the FAA or NASA test his theoretical model, which you think works. Have you seen any indication that they are going to do that?

Captain **O'Donnell.** No, Mr. Chairman. In fact, the opposite may be the case. I think everybody is aware—the gentleman from ATA just mentioned it—that there is a substantial feeling in the industry that the FAA is cutting back on much of its R. & D. This is one of the areas that we feel could be very easily and quickly cut back.

Mr. **Gore.** I hope that will not be the case, but we will see.

Let us talk about cabin interiors for a moment. Your organization participated in the SAFER Committee; is that correct?

Captain **O'Donnell.** Yes, sir.

Mr. **Gore.** Have you been satisfied with the research being done as a result of that committee's recommendations, Mr. O'Brien?

Mr. **O'Brien.** I think the SAFER Committee has identified all of the pertinent areas that should be examined. As we have heard this morning, there is a lot of research and development effort going into these areas. I guess if we were going to be critical in any form, it would be to suggest that this effort could be speeded up a little bit.

Mr. **Gore.** Could you identify any particular deficiencies in the research effort resulting from the SAFER Committee report, aside from the general slow pace?

Mr. **O'Brien.** I think you hit it correctly. It is the slow pace. An example would be the crash test that is programed for 1984 now. I think that, not being unrealistic at all, that could be moved up without too much of a problem.

Mr. **Gore**. I have some other questions, but I would like to recognize my colleague, Mr. Hollenbeck.

Mr. **Hollenbeck**. On the subject of deicing procedures, I have a two-part question. Do you have any suggestions for improvements with the procedures, and are you aware of any additional material or studies that we may not have been made aware of today for improving those procedures or matters along those lines.

Captain **O'Donnell**. Mr. Hollenbeck, I think it is important that the response that we give has to attach itself to what we have read in the newspapers. I think there is clear reporting in the newspapers in Washington to suggest that within the industry some segments do not have a clear understanding of what the deicing procedures are or what the mixtures should be. It is obvious, again from the newspaper reports, that there is a feeling that there may be a contributory cause here.

Yes, there have been studies, some by the U.S. Air Force as far back as 1957, that described research done by the military as to how the glycol mixture should be put together, what ratios, what additives should be put in it, what precautions should be made in the glycol and the anti-icing and deicing procedures. In 1976, that study was updated, and we have copies of that. If the committee requests it, we will provide it for the record. Those are available; they are in the public record; they are U.S. Air Force research programs.

Mr. **Hollenbeck**. Thank you. Would it be practical, mechanically or administratively, to have a deicing mechanism or truck holding the deicing spray present near the beginning of the runway in this kind of weather situation to be available for last-minute check and procedure?

Captain **O'Donnell**. That is a possibility. You know, I have flown for many, many, many years out of Boston. We get a little bit rougher weather up there than you do down here in Washington, D.C. Every winter we do go through a series of storms up there that do require deicing the aircraft and anti-icing before takeoff. Very simply, the airlines I am familiar with have specific procedures to brush the snow off the aircraft, and put a coating of glycol on. The mixture was awfully important.

In those days—and I have not flown for the last 10 years as an airline pilot—we made sure that the second officer, our flight engineer, went back and checked the surface of the wing. If we had a question, we would make him open the door, go out and walk around the aircraft, because once you push those throttles forward, he is on board with you. You know, when you rotate the aircraft, you hope it flies. Therefore, the only way to make sure of that is to make the decisions yourself.

I cannot accept one of the statements I heard this morning by someone with respect to how glycoling is done. I think that the glycol systems of today are no improvement over what they were 20 years ago. There is very little improvement, and I am not sure you need any improvements. But there has to be closer control over the quality and the mixtures and the timing and the application of it. We used to go to a hangar and have them deiced, have the snow brushed off and hosed down, and 15 or 20 minutes before we are cleared for departure, we would get a glycol treatment.

I think there are procedures available. I am not sure necessarily the airlines would buy it because of the economics of having a truck at the end of the runway. It is clear, from almost every study that I have heard, and particularly the Air Force studies, you do not put glycol on an aircraft that has snow on it; it will melt and turn to ice.

Mr. **Hollenbeck**. Thank you. We have a vote right now. I would like to ask the chairman's consent to submit some further questions for the record and to ask you, Captain O'Donnell, if you could make available to the staff some more information as to the title and the date of that Air Force document so that we might possible submit it for the record.

Mr. **Gore**. Without objection, it will be entered in the record at this point.

[Material to be supplied follows:]

TECHNICAL MEMORANDUM WCLT TM57-162

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DEVELOPMENT AND EVALUATION OF ANTI-ICING AND DEICING FLUIDS

Prepared by
Materials Laboratory
Directorate of Laboratories

3 December 1957

Task No. 73121

Wright Air Development Center
Air Research and Development Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

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Technical Memorandum
WCLT TM 57-162
3 December 1957

Materials Laboratory
Directorate of Laboratories
Task No. 73121

DEVELOPMENT AND EVALUATION OF ANTI-ICING AND DEICING FLUIDS

I. PURPOSE:

To develop and evaluate anti-icing and deicing fluid formulations to replace Specification MIL-E-5559, MIL-D-8243 and MIL-E-9500 anti-icing and deicing materials.

II. FACTUAL DATA:

1. In the past, several different materials have been used for prevention and removal of frost and ice from aircraft on the ground. Removal has been accomplished with heated ethylene glycol, Specification MIL-E-5559, and prevention with cold deicing-defrosting fluid Specification MIL-D-8243. Specification MIL-E-9500 ethylene glycol has been used for in-flight deicing and radomes. Composition and properties of these fluids are given in Appendix I.

2. Test procedures for slush and solid points, flash point, crazing test, and corrosion tests are given in Appendix II.

3. It was desired to improve the flammability and package slush point properties of the existing fluids so a number of additives were tried in the proportion of 15 per cent (by weight) of additive, 15 per cent water, and 70 per cent ethylene glycol. Results are in Appendix III, Table 3.

4. Slush point properties of many other additives have been previously reported in Memorandum Report TSEAM-M5260, 20 November 1946. The following chemicals showed promise:

isopropyl alcohol
triethanol amine
boric acid
ammonium carbonate
dioctyl sodium sulfosuccinate
zinc stearate
sucrose
dextrose

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5. Several wetting agents were tried as freezing point depressant additives at several water concentrations. Results are in Appendix III, Table 4.

6. Due to the thixotropic nature of a nitro compound, several nitrogenous alcohols were tried as additives at several water concentrations. Results are in Appendix III, Table 5.

7. Figure 1, Appendix III is the slush point curve obtained for the following composition:

64.4	grams	ethylene glycol
32.1	"	propylene glycol
2.0	"	water
0.5	"	di-(2-ethylhexyl) sulfosuccinate
1.0	"	K_2HPO_4

Figure 2, Appendix III is the freezing point curve for pure ethylene glycol. It may be seen that mixed glycols give very low slush points with high glycol concentrations.

8. A flash point over 200°F is necessary so that the deicing fluid can be heated safely. It was found that a mixture of 70 per cent ethylene glycol, 15 per cent water and 15 per cent Ansul ether 161 had a flash point of over 200°F, but substitution of isopropyl alcohol for one-third of the Ansul ether 161 reduced the flash point to 120-125°F.

9. The crazing power of mixed glycol deicing fluids and Specification MIL-D-8243 fluids was compared. Results are in Appendix IV, Tables 6, 7 and 8.

10. A 3:1 ratio by weight of ethylene to propylene glycol was used to test inhibition of magnesium corrosion. Panels (1 X 2 inches) of AZ-31 magnesium treated with Type I, Specification MIL-M-3171, were immersed for 7 days at 100°F. Solutions containing one pph of sodium benzoate, sodium nitrate, and sodium nitrite severely etched the magnesium. Solutions containing 4.5 pph of triethanolamine phosphate and one pph of dibasic potassium phosphate inhibited corrosion to less than 1 mg. change in weight.

11. Mixed glycol solutions were compared in corrosion tests with Specification MIL-D-8243 type deicing fluid using dibasic potassium phosphate as the corrosion inhibitor (Formulas B and C, Table 6, Appendix IV). Steel panels (Specification QQ-S-636) were immersed for two days at 160°F. The solutions were cooled to 100°F and 2024 aluminum panels coupled to AZ-31 magnesium panels (treated with Type III, Specification MIL-M-3171) were immersed in each solution for two days. The couples were then suspended for three days in 100 per cent relative humidity at 75°F. Results are in Appendix V, Table 9. The Specification MIL-D-8243 control formula (inhibited with triethanolamine phosphate and sodium mercaptobenzothiazole) has been previously found to be unsatisfactory in this type of test (WCRT TM 54-130).

12. A wetting agent was found to be necessary to enable glycols to spread satisfactorily on aluminum. Nonionic types are precipitated from solution at temperatures below 180°F. Anionic types are generally good wetting agents for metals. Di-(2-ethylhexyl) sulfosuccinate was chosen

for testing because of its availability. A glycol solution containing one-half per cent of the latter wets aluminum, enamel and lacquer as well as a solution containing 20 per cent isopropyl alcohol.

III. CONCLUSIONS:

1. Ethylene glycol alone will not meet the target requirement for package slush point unless diluted with over 20 per cent water. Therefore, another freezing point depressant should be added to give a low package slush point.

2. Isopropyl alcohol cannot be used to depress the package slush point because only 5 per cent depresses the flash point to under 125°F.

3. Propylene glycol is the best additive of those tested from the standpoint of package slush point. At approximately 70 parts ethylene glycol, 15 parts additive, and 15 parts water, the slush point with propylene glycol as the additive is below -90°F, whereas the next best, trimethyl phosphate, has a slush point of -76°F.

4. Of the inhibitors tested, only triethanolaminephosphate and dibasic potassium phosphate were effective. However, triethanolaminephosphate will stain white enamel.

5. Di-(2-ethylhexyl) sulfosuccinate was found to be satisfactory for wetting aircraft surfaces.

6. It is concluded that the best mixture for an anti-icing and deicing fluid is a 3:1 ratio of ethylene and propylene glycols with dibasic potassium phosphate (one per cent) to inhibit corrosion, sufficient water to hold the inhibitor in solution (9-10 per cent), and 0.5 per cent di-(2-ethylhexyl) sulfosuccinate.

IV. RECOMMENDATIONS:

As a result of this work, a deicing fluid with the composition listed in paragraph 7 of Section II has been published as Specification MIL-A-8243A (USAF).

COORDINATION:

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PREPARED BY:

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PUBLICATION REVIEW

This report has been reviewed and is approved

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APPENDIX I

COMPOSITION AND PROPERTIES OF SPECIFICATIONS MIL-E-5559, MIL-D-8243 AND MIL-E-9500

TABLE 1

COMPOSITION OF SPECIFICATIONS MIL-E-5559, MIL-D-8243 AND MIL-E-9500

Component	Weight Per Cent		
	MIL-E-5559	MIL-D-8243*	MIL-E-9500
Ethylene Glycol	94.0	60-80	99.5
Isopropyl Alcohol	-	10-20	-
Water	2.5-3.0	0-20	0.5
Corrosion Inhibitor	2.4-3.0	0-2	-
Dextrose (thickener)	-	0-10.5g./100 ml.	-

* This specification was a qualification type with composition optional with the manufacturer.

TABLE 2

PROPERTIES OF SPECIFICATIONS MIL-E-5559, MIL-D-8243 AND MIL-E-9500

Property	MIL-E-5559	MIL-D-8243	MIL-E-9500	Target
Flash Point, °F	220	80	220	Above 200
Corrosion	Good	Good	Poor	Very Good
Melting Power	Good	Good	Good	Good
Crazing of Plastic	Good	Fair	Excellent	Excellent
Effect on Paints & Rubber	Good*	Fair	Good	Good
Package Slush Point, °F	About -10	-50	+10	Below -50

* discolors white enamel

APPENDIX II

TEST PROCEDURES

1. Slush Point. - Pour 5 ml. of the solution into a test tube and slowly cool down in a dry ice-acetone bath while continually stirring with a 76 mm immersion ASTM thermometer with a range from minus 112 to plus 70°F. Cool the solution to from 5-15° below the expected slush point and withdraw the thermometer so that it is coated with the slushy solution. Record the temperature at which the bulk of the material begins to slide.

2. Solid Point. - Conduct the test in the same manner but do not withdraw the thermometer. Continue stirring slowly until the thermometer can no longer be worked and record the temperature.

3. Flash Point. - Conduct the flash point test in accordance with the test method "Flash Point by means of Tag Closed Tester" as given in Specification VV-L-791.

4. Crazing. - Conduct the crazing test in accordance with Method No. 3035 of Specification L-P-406.

5. Corrosion. - Conduct the corrosion tests in accordance with Specification MIL-R-25134 except that the coupled panels shall be immersed in the solution for two days and suspended in 100 per cent humidity for three days.

APPENDIX III

SLUSH AND SOLID POINTS OF DEICING FLUIDS

TABLE 3

SLUSH AND SOLID POINTS OF MIXTURES OF ETHYLENE GLYCOL (70 per cent)*, WATER (15 per cent), AND AN ADDITIVE (15 per cent)

Additive	Slush Point °F	Solid Point °F	Remarks
Ansul ether 161	-68	below -80	
dibasic ammonium phosphate	-62	below -80	some precipitate
dimethyl sulfoxide	-71	below -90	
triethyl phosphate	-73	below -80	
trimethyl phosphate	-76	below -80	
sodium borate	-55	-80	solution cloudy
cyclohexanol	-65	below -80	
2-nitropropane	-92(?)	below -100	excess additive decanted remainder thixotropic
ethyl orthosilicate	-79	below -90	same as above
sodium nitrate	-60	-85	some precipitate
monobasic potassium phosphate	-75	below -90	white gelatinous precipitate

* All per cents by weight. Ethylene glycol was technical grade.

TABLE 4

SLUSH POINTS OF ETHYLENE GLYCOL (Spec. MIL-E-5559), WETTING AGENT, AND WATER SOLUTIONS

Wetting Agent	Per Cent (Volume) Water			
	0	29	50	71
Triton X-100*	-17°F	-75°F	-34°F	+6°F
Nonic #218*	-27°	-72°	-27°	6°
Tween 20*	-36°	-65°	-28°	6°
Dioctyl Sodium Sulfosuccinate **	-19°	-50°	-14°	6°

* 80 ml ethylene glycol, 20 ml. wetting agent
** 80 ml ethylene glycol, 20 g. wetting agent

TABLE 5

SLUSH POINTS OF ETHYLENE GLYCOL (Spec. MIL-E-5559), ADDITIVE, AND WATER SOLUTIONS

Additive	Per Cent (Volume Water			
	0	29	50	71
Dimethyl Sulfoxide (1)	-47°F	-79°F	-39°F	+6°F
Triethanolamine (1)	-19°	-62°	-34°	+6°
Diethylaminoethanol (1)	-35°	-58°	-27°	+7°
2-amino-2-methyl-1,3propanediol (2) (3)	-16°	-68°	-27°	+7°
2-nitro-2-methyl-1-propanol (2)	-40°	(4)	(4)	+8°
2-nitro-2-methyl-1,3-propanediol (2) (3)	-25°	-69°	-32°	+8°
2-nitro-2-ethyl-1,3-propanediol (2)	-29°	-89°	-23°	+7°
2-amino-2-methyl-1-propanol (1) (4)	-17°	-58°	-23°	+8°
2-amino-1-butanol (1)	-42°	-59°	-33°	+4°
2-amino-2-ethyl-1,3-propanediol (1)	-34°	-50°	-28°	+7°
2,2'-Iminodiethanol (1)	-33°	-49°	-29°	+5°

(1) 4:1 ratio by volume, ethylene glycol to additive
(2) 4 ml ethylene glycol to 1 gram additive
(3) precipitate formed on standing
(4) thixotropic

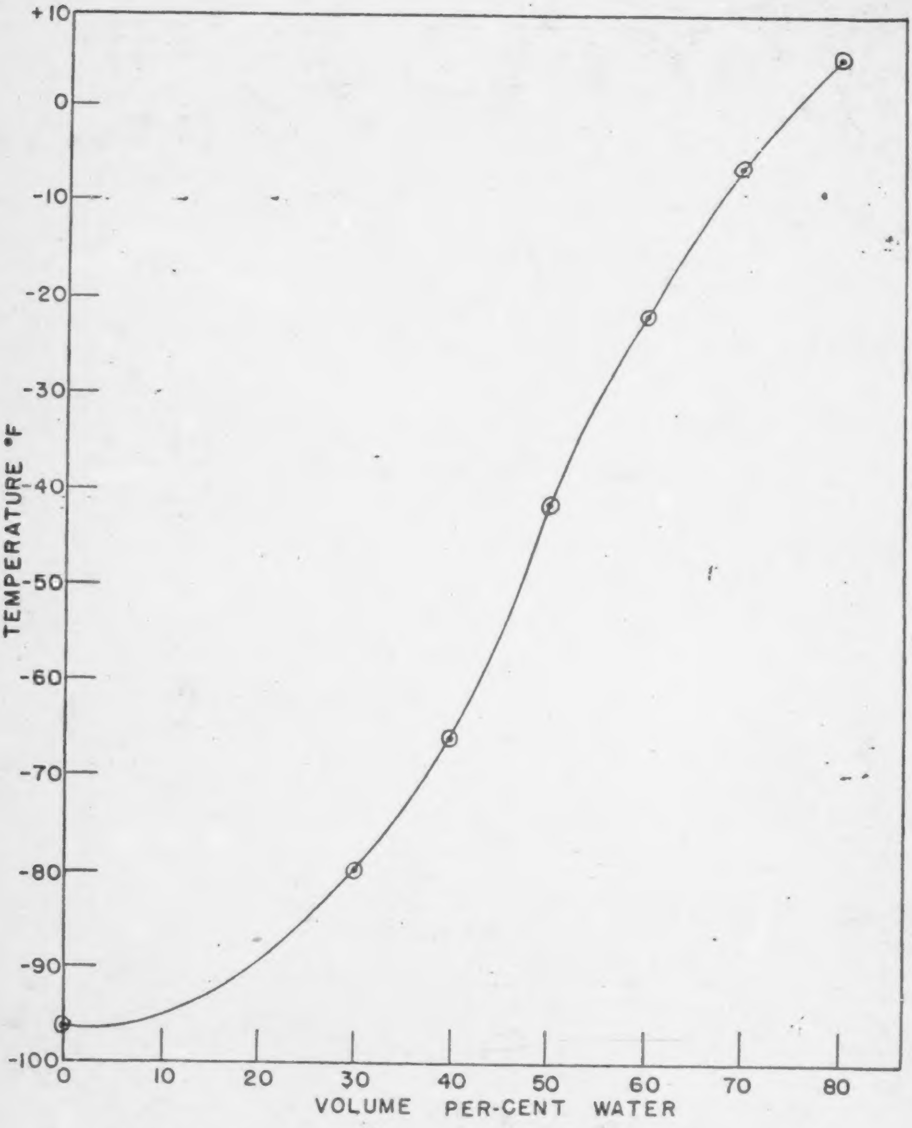

FIGURE I. SLUSH POINTS, MIXED GLYCOL DEICING FLUID AND WATER

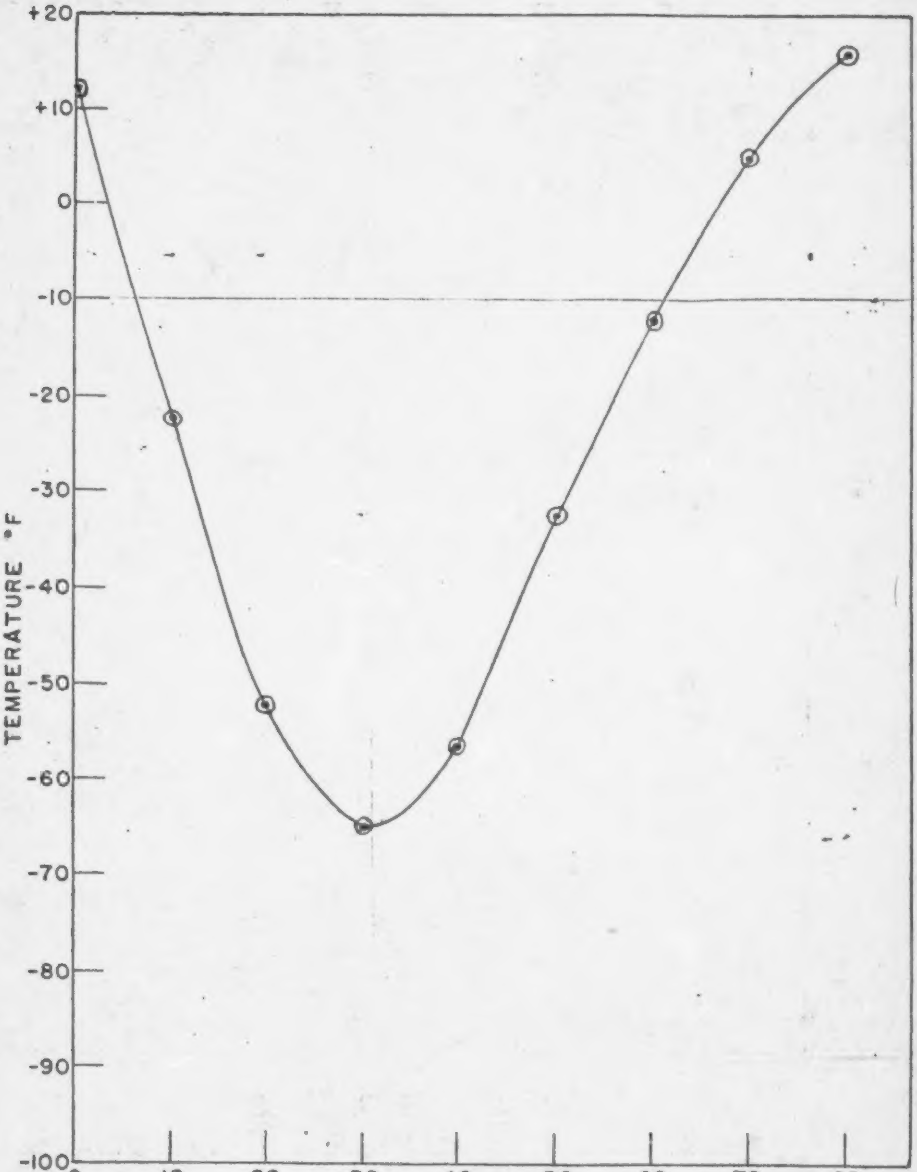

FIGURE 2. FREEZING POINTS, PURE ETHYLENE GLYCOL AND WATER

APPENDIX IV

CRAZING OF TRANSPARENT PLASTICS

TABLE 6

COMPOSITION OF DEICING FLUIDS USED FOR CRAZING TEST

Component	Fluid (per cent by weight) A	B	C	D
Ethylene Glycol	73.0	78.0	73.0	60.0
Propylene Glycol	25.0	20.0		
Isopropyl Alcohol			14.0	
SD-1 Ethyl Alcohol				26.0
Water	2.0	2.0	13.0	14.0

TABLE 7

CRAZING OF PLEXIGLASS 55 AT 5000 psi BY DEICING FLUIDS*

Fluid	First Crazing	Appearance, 30 min.	Minimum Stress Level 30 min.
A	7 min.	many fine to deep fissures	4300
B	8 min.	many fine to deep fissures	4260
C	2 min.	many surface fissures	4400
D	1 min.	many deep fissures	4210

* Annealed Plexiglass 55 (Spec. MIL-P-8184), prestressed 10 min., outer fiber stress 5000 psi for 30 minutes.

TABLE 8

CRAZING OF ANNEALED PLEXIGLASS II BY GLYCOL DEICING FLUIDS

Fluid	Outer Fiber Stress	First Crazing	Appearance	Time	Minimum Stress Leve
A	3000	over 24 hours	few medium fissures	92 hrs.	2910
B	"	" " "	" " "	" "	2920
A	4000	40 minutes	many deep fissures	19 hrs.	3540
B	"	35 "	" " "	" "	3530

APPENDIX V

CORROSION

TABLE 9

CORROSION INHIBITION BY DIBASIC POTASSIUM PHOSPHATE

Fluid Formula*	Per Cent K_2HPO_4	Weight Change, Steel, mg.	Appearance	
			Aluminum	Magnesium
C	0.18	0.0	very slight pitting	no corrosion
B	0.25	+0.2	corrosion on faying surface	pitting on fayin surface
B	0.50	+0.1	slight pitting	very slight pitting
B	0.75	0.0	very slight pitting	no corrosion

* Formula C was made with fresh ethylene glycol. The glycols used in Formula B had been stored in steel drums for approximately 2 years. Formulations are in Table 6, Appendix IV.

"DOW" AIRCRAFT DEICING FLUID 146A

technical
data
sheet

This is an example of a
commerical Aircraft deicing fluid.

NOTE: IT DOES NOT MEET MIL-A-8243 requirements.

DOW Aircraft Deicing Fluid 146A is composed of ethylene glycol, higher glycols, a wetting agent, an antifoam, and corrosion inhibitors. It has excellent anti-icing and deicing characteristics and storage stability, and the 70% use dilution remains fluid for easy application at all temperatures. This fluid has improved biodegradeability with low fish toxicity. The concentrate has a high flash point with no flash point at use dilution, which allows safe application around hot surfaces.

DOW Aircraft Deicing Fluid 146A is available in drums and bulk quantities. Further information may be obtained by writing The Dow Chemical Company, Transportation Chemicals, 9008 Building, Midland, Michigan 48640.

FREEZING PROPERTIES

The freezing point of DOW Aircraft Deicing Fluid 146A will increase from a minimum freezing point at approximately a 70% concentration in water to a freezing point of approximately 0°F at 100% concentration.

Deicer Concentration (percent by volume)	Freezing Point
70%	−60°F ✓
60%	−56°F
50%	−31°F
20%	+19°F

Typical Properties of "DOW" Aircraft Deicing Fluid 146A

General:	Specific Gravity @ 60°F	1.1061-1.1161
	pH 100% Deicing Fluid	10.0-10.6
	pH 50% Deicing Fluid	9.8-10.4
	Refractive Index @ 25°C	1.4234-1.4264
	Water, maximum	5.5%
	Flash point COC,	
	min. 100%	255°F
	min 75% (in H_2O)	none
	Appearance	Clear, orange liquid

An independent testing laboratory has certified that DOW Aircraft Deicing Fluid 146A is in full compliance with the Douglas CSD-1 and the Boeing D6-17487 specifications.

Methods of analysis available on request.

NOTICE – The information herein is presented in good faith, but no warranty, express or implied, is given nor is freedom from any patent owned by The Dow Chemical Company or by others to be inferred

DOW CHEMICAL U.S.A.
AG-ORGANICS DEPARTMENT • MIDLAND, MICHIGAN 48640

CORROSION PROPERTIES

Tests run in accordance with Boeing and Douglas specifications indicate that DOW Aircraft Deicing Fluid 146A is noncorrosive to the metals commonly used in aircraft manufacture and spray equipment. These tests for corrosive action show that corrosion losses on the specified types of aluminum, aluminum-clad alloy, brass, copper, steel, and magnesium are nil.

EFFECTS ON PLASTICS, RUBBER AND PAINT

Under recommended conditions of use, DOW Aircraft Deicing Fluid 146A will not harm plastics, paints, or rubber normally used in aircraft construction. These materials of construction have been tested according to the Douglas and Boeing specifications.

TOXICOLOGICAL PROPERTIES

DOW Aircraft Deicing Fluid 146A presents only limited hazards in handling. Based upon human experience and upon animal tests conducted by Dow, this product has been shown to cause only very mild transient eye irritation and very little skin irritation unless exposures are excessive and continuous, such as may occur if saturated clothing is worn next to the skin. Under recommended conditions of use, ingestion of toxic amounts should not be a problem. However, it should be borne in mind that this fluid is principally ethylene glycol, and ingestion of large amounts may be harmful or fatal. Human experience indicates that man seems to be more susceptible than laboratory animals to injury from ingestion of ethylene glycol. The lethal dose for humans of ethylene glycol appears to be approximately three ounces for a 150-pound adult. The inhalation of mists in particular and vapors of ethylene glycol have produced toxic effects. If large amounts are ingested, induce vomiting and call a physician immediately. Maintenance men and others exposed to the fluid or its mists and vapors should be instructed to practice good personal cleanliness. Protective equipment should be worn to prevent inhalation of mists or sprays and continuous contamination of the skin. The treatment of the aircraft should be carried out in well ventilated areas.

(See Use and Handling Sections)

It is recommended that ventilator or air intake ducts should not be directly sprayed with deicing fluid. Special care should be taken to keep heavy mists away from the ventilator or air intake ducts. This precaution is essential to minimize the possibility of toxic fumes entering the aircraft cabin.

RECOMMENDATIONS FOR USE AND HANDLING OF "DOW" AIRCRAFT DEICING FLUID 146A

GENERAL:

DOW Aircraft Deicing Fluid 146A is most effective when used in concentrated form. Dilution with water reduces the fluid's capacity to remove ice and frost. However, it is completely miscible with water when the proper mixing procedure is observed.

USE:

- SEE SECTION ON TOXICOLOGICAL PROPERTIES FOR SUGGESTED PRECAUTIONS FOR SAFE HANDLING
- Hot concentrated deicer gives the most effective deicing action, although concentrated deicer may be applied cold.
- For best results apply diluted fluid hot (160°F to 190°F).
- Do not dilute DOW Aircraft Deicing Fluid 146A by more than is specified in Table I—*Minimum Concentrations for Effective Deicing at Various Temperatures.*
- Apply at pressures as high as possible, but not exceeding 100 psi for fabric surfaces, nor 300 psi for metal surfaces.
- Be sure no ice particles remain in control surfaces hinges.
- Even though the flash point of DOW Aircraft Deicing Fluid 146A is above 255°F, care should be taken when applying it around hot surfaces such as heater or engine exhausts.

- Be sure to wear protective clothing when spraying deicing fluids, avoid inhalation exposure to spray mists, and avoid contamination of clothing.

MIXING:

The importance of thoroughly mixing diluted deicing fluid cannot be overemphasized, since glycols and water are not readily miscible at low temperatures. Unless the two fluids are thoroughly agitated, the glycol will form a layer at the bottom of the container and the water will float on top of the glycol.

If cold water and cold glycol are mixed with little or no stirring, very little blending of the water and glycol occurs. The amount of mixing may be so slight, in fact, that the top layer containing nearly all water may freeze at temperatures only slightly below 32°F.

To insure effective dilution of the deicing fluid, the following steps should be carefully followed:

1. Place 1/2 to 2/3 of the necessary dilution water in the blending tank.
2. Using constant agitation, pour in the required amount of deicing fluid.
3. Finally, add the remainder of the water and continue agitation of solution for another 10 to 15 minutes.

This thoroughly blended mixture may be stored for prolonged periods of time without danger of separation.

(The use of hot water eliminates many potential dilution problems.)

A recirculating pump attached to the tank affords the best means of agitating the mixture. Manual stirring is effective, but requires more time and effort. An air hose may be used to mix the solution, but prolonged aeration may result in excess foam production.

The formation of a film of ice on diluted deicing fluid indicates that proper mixing has not been accomplished. In this event, the ice should be broken and the solution agitated. Application of heat at this point is beneficial.

STORING:

DOW Aircraft Deicing Fluid 146A, concentrated or diluted, is compounded to allow satisfactory storage in steel drums at any temperature above the freezing point of the fluid. It will neither corrode nor clog standard spraying equipment.

EQUIPMENT:

Standard truck-mounted spraying equipment is recommended for application of deicing fluid. For best results the spray tank should be equipped to heat the fluid to above 160°F. If spray equipment is not available, mops, brooms, or soft-bristled brushes may be used to apply deicing fluid.

PREVENTION OF ACCUMULATIONS OF FROST, ICE AND SNOW

GENERAL:

Whenever possible, efforts should be made to prevent the formation of large amounts of frost, ice or snow on parked aircraft, since prevention is more economical than removal.

FROST:

Frost may be easily prevented by the application of a thin layer of cold, concentrated fluid to the aircraft surface. The fluid may be applied in a fine spray or with mops or swabs. The excellent "holding" property of DOW Aircraft Deicing Fluid 146A provides a film of maximum thickness with minimum loss due to run-off, even in the presence of oily films.

FREEZING RAIN AND ICE:

Light accumulations of freezing rain and ice may be prevented by application of cold, concentrated deicer in the manner prescribed for prevention of frost. Large amounts of freezing rain, however, will in time dilute and wash away deicing fluid. As such dilution occurs, reapplication of deicing fluid is required to prevent ice formation. If wing covers are available, a coating of cold, concentrated deicing fluid should be applied to the aircraft before the covers are installed. Care should be taken to prevent rain from blowing under the covers as this may cause excessive dilution and freezing of the covers to the aircraft.

SNOW:

Snow should be swept off wing surfaces at frequent intervals during the snowfall. When wing covers are used, a layer of cold, concentrated deicer may be applied to the aircraft before the covers are installed to prevent the freezing of the covers to the wing and subsequently to insure easy removal. (If deicing fluid is applied before or during a snowfall, the melting snow may form a slush which eventually refreezes and may be difficult to remove.)

REMOVAL OF FROST, ICE AND SNOW

GENERAL:

If severe weather conditons rule out preventive deicing, accumulated deposits must be removed.

FROST:

Removal of accumulated frost is best accomplished by the application of DOW Aircraft Deicing Fluid 146A heated to above 160°F. If facilities for heating are not available, cold undiluted deicer may be used, but the deicing operation takes longer.

FREEZING RAIN AND ICE:

The force of a stream of heated deicing fluid under pressure assists measurably in removal of accumulations of freezing rain and ice. For best results, the use directions should be carefully followed. The best results are obtained with hot concentrated deicer applied under pressure. Care should be taken to insure that no ice particles remain in control surface hinges.

SNOW:

Snow should be swept or brushed off the aircraft surfaces first. Any ice remaining after sweeping may be removed by the method previously described.

TABLE I

MINIMUM CONCENTRATIONS FOR EFFECTIVE DEICING AT VARIOUS TEMPERATURES

If the anticipated ambient temperature is:	The minimum percent of DOW Aircraft Deicing Fluid 146A in solution should be:
30°F	30%
20°	35%
10°	40%
0°	50%
−10°	60%
−20°	65%

[illegible]

MIL-A-8243C
17 November 1980
SUPERSEDING
MIL-A-8243B
5 March 1965

Chem
wd

MILITARY SPECIFICATION

ANTI-ICING AND DEICING-DEFROSTING FLUIDS

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers the requirements for two types of anti-icing and deicing-defrosting fluids for use on aircraft.

1.2 Classification. The anti-icing and deicing-defrosting fluids covered by this specification shall be of the following types, as specified (see 6.2):

Type I - Standard
Type II - Standard with Inhibitor

2. APPLICABLE DOCUMENTS

2.1 Issues of documents. The following documents of the issue in effect on date of invitation for bids or request for proposal form a part of this specification to the extent specified herein.

SPECIFICATIONS

FEDERAL

QQ-A-250/4 -Aluminum Alloy 2024, Plate and Sheet.
QQ-A-250/5 -Aluminum Alloy Alclad 2024, Plate and Sheet.
QQ-A-250/13 -Aluminum Alloy Alclad 7075, Plate and Sheet.

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Engineering Specifications and Standards Department (Code 93), Naval Air Engineering Center, Lakehurst, NJ 08733, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

NO INFORMATION REQUIREMENTS

FSC 6850

FEDERAL (Continued)

QQ-M-44	-Magnesium Alloy Plate and Sheet (AZ31B).
QQ-P-416	-Plating, Cadmium (Electrodeposited).
PPP-D-729	-Drum, Shipping and Storage, Steel, 55-Gallon (208 Liters).
PPP-P-704	-Pail, Metal, (Shipping, Steel 1 Through 12 Gallon).

MILITARY

MIL-M-3171	-Magnesium Alloy, Processes for Pretreatment and Prevention of Corrosion on.
MIL-S-7952	-Steel, Sheet and Strip, Uncoated, Carbon (1020 and 1025) (Aircraft Quality).
MIL-A-8625	-Anodic Coatings, for Aluminum and Aluminum Alloys.
MIL-T-9046	-Titanium and Titanium Alloy, Sheet, Strip and Plate.

STANDARDS

MILITARY

MIL-STD-105	-Sampling Procedures and Tables for Inspection by Attributes.
MIL-STD-129	-Marking for Shipment and Storage.

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific acquisition functions should be obtained from the acquisition activity or as directed by the contracting officer.)

2.2 Other publications. -The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ANSI/ASTM D 92-79	-Flash and Fire Points by Cleveland Open Cup.
ANSI/ASTM D 97-66	-Pour Point of Petroleum Oils.
ASTM D 270-65	-Petroleum and Petroleum Products, Sampling.

ANSI/ASTM D 1122-58	-Specific Gravity of Engine Antifreezes by the Hydrometer.
ANSI/ASTM D 1123-79	-Water in Engine Coolant Concentrate by the Iodine Reagent Method.
ANSI/ASTM D 1176-71	-Sampling and Preparing Aqueous Solutions of Engine Antifreezes or Antirusts for Testing Purposes.

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

NATIONAL MOTOR FREIGHT TRAFFIC ASSOCIATION, INC., AGENT

National Motor Freight Classification.

(Application for copies should be addressed to the National Motor Freight Traffic, Tariff Department, 1616 P Street, N.W., Washington, DC 20036.)

UNIFORM CLASSIFICATION COMMITTEE, AGENT

Uniform Freight Classification Rules.

(Application for copies should be addressed to the Uniform Classification Committee, Room 1106, 222 South Riverside Plaza, Chicago, IL 60606.)

CODE OF FEDERAL REGULATIONS

CFR Title 49, 100-199 -Transportation.

(Application for copies should be addressed to the Superintendent of Documents, Government Printing Office, Washington, DC 20402.)

(Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

3. REQUIREMENTS

3.1 Material. The material shall be basically a mixture of ethylene glycol and propylene glycol in a three to one ratio respectively. The material shall be completely miscible and homogeneous.

3.2 Composition. The composition of the anti-icing and deicing-defrosting fluids furnished under this specification shall consist of four components for type I and five components for type II as specified in table I.

3.3 Chemical and physical properties. The chemical and physical properties of the finished anti-icing and deicing-defrosting fluid shall conform to the requirements specified in tables I and II when tested as specified in 4.5.

3.4 Workmanship. The anti-icing and deicing-defrosting fluids furnished under this specification shall be manufactured by such processes as to produce a homogeneous and uniform product free from suspended material.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Certificate of compliance. Where certificates of compliance are submitted, the Government reserves the right to check test such items to determine the validity of the certification.

4.3 Inspection conditions. Unless otherwise specified, all inspections shall be performed in accordance with the test conditions specified in the applicable paragraphs in this specification.

4.4 Quality conformance inspection. Quality conformance inspection shall consist of the tests specified in table III, and the examinations specified in 4.4.4 through 4.4.6.

4.4.1 Reduced testing and examination. Unless otherwise specified (see 6.2), reduced testing and examination may be performed on the lot if the contractor has previously fully tested and furnished satisfactory material under this specification. The contractor shall certify that the lot of material furnished is manufactured under the same conditions using the same formulation and raw materials as previously tested and conforms to all requirements of this specification. The following minimum tests and examination shall be performed:

Visual examination	4.4.4
Water	4.5.2
Corrosiveness	4.5.8
Pour point	4.5.10 (undiluted material only)
Specific gravity	4.5.11

If during reduced testing, a lot of material fails to meet any requirement of the specification, normal testing shall be reinstituted and continued until two successive lots meet all requirements of the specification, after which reducted testing may be resumed.

4.4.2 Lot formation. A lot shall consist of all the anti-icing and deicing-defrosting fluid produced by one manufacturer, at one plant, from the same materials, and under essentially the same manufacturing conditions, provided the operation is continuous and does not exceed a 24 hour period. In the event the process is a batch operation, each batch shall constitute a lot (see 6.3).

4.4.3 Sampling for tests. The sample for end item tests shall be randomly selected in accordance with table V. The test portion of each sample unit shall be obtained as specified in ASTM D 270-65. Two 2-liter composite samples, consisting of equal parts of each sample unit selected, shall be subject to all the applicable tests of this specification. The tests shall be performed in duplicate, one determination from each composite sample. If the average results for any test fail to meet the requirement, the lot represented by the sample shall be rejected.

4.4.4 Visual examination of the end item. The sample unit for this examination shall be one filled unit container. The content shall be examined for the defects listed in table IV. The sample size shall be in accordance with table V. Any evidence of nonconformance shall be cause for rejection of the lot.

4.4.5 Inspection of filled containers. The sample unit for this examination shall be one filled container. The sample size shall be as specified in table V. The lot shall be unacceptable if the average net content per container for all units examined is less than specified.

4.4.6 Packaging inspection. An examination shall be made to determine if the packaging, packing and marking comply with the requirements of Section 5 of this specification. The sample unit shall be one shipping container fully prepared for delivery. Each sample unit shall be examined for defects listed in table VI. The lot size shall be the number of shipping containers in the lot. The examination shall be in accordance with MIL-STD-105, inspection level S-2 and acceptable quality level (AQL) 2.5 defects per hundred units.

4.5 Test methods.

4.5.1 1, 2-glycol content.

4.5.1.1 Reagents. The following reagents shall be used in the determination of 1, 2-glycol content of the anti-icing and deicing-defrosting fluid (i.e., glycols having adjacent hydroxyls in their molecular structure):

a. 0.4N sodium periodate solution (prepared by weighing out exactly 10.6 grams of metasodium periodate ($NaIO_4$) and dissolving in sufficient distilled water to make 1 liter of solution).
b. 0.2N sodium thiosulfate solution.
c. 30 percent potassium iodide solution.
d. Starch solution.
e. 20 percent sulfuric acid solution.

4.5.1.2 Procedure. Three and five-tenths to four grams of the anti-icing and deicing-defrosting fluid shall be weighed by difference in a 250-milliliter volumetric flask. The mass shall be determined to the nearest 0.1 milligram. The flask shall then be filled to the 250-milliliter mark with distilled water and the solution mixed thoroughly. A 10 milliliter (ml) aliquot of the solution shall be transferred to a 500 milliliter iodine flask. Fifty milliliters of the 0.4N sodium periodate solution shall then be added, the flask stoppered and the mixture allowed to react. Two blanks shall be run in the same manner. After 1 hour, 150 milliliters of distilled water shall be added to the sample mixture, followed by the addition of 20 milliliters of the 20 percent sulfuric acid solution and 40 milliliters of the 30 percent potassium iodide solution. (The potassium iodide solution should be added by pouring it around the stopper thus forming a liquid seal between the stopper and the neck of the flask to absorb any liberated iodine vapors.) The sample mixture shall be allowed to react for 10 minutes, agitating frequently, after which the neck and sides of the flask shall be rinsed with distilled water from a wash bottle. The sample and the blanks shall then be titrated to a pale yellow iodine color with standardized 0.2N sodium thiosulfate. Two milliliters of starch solution shall be added and the solutions titrated to the disappearance of the blue color. The blanks should each require 95 to 100 milliliters of the thiosulfate and the sample mixtures 78 to 90 milliliters. The 1, 2-glycol content shall be computed as follows:

$$\text{Percent 1, 2-glycol content} = \frac{0.0330 \times 25 \times (B - S) \times N}{W} \times 100$$

where

B = ml thiosulfate solution required by the blank (average of two blank runs).
S = ml of thiosulfate solution required by the sample aliquot.
N = normality of the thiosulfate solution.
W = mass of the sample in grams.

4.5.2 Water content. Water content shall be determined in accordance with ANSI/ASTM D 1123-79.

4.5.3 Phosphate content.

4.5.3.1 Preparation of reagent. Fifty grams of crystalline magnesium chloride ($MgCl_2.6H_2O$) and 100 grams of ammonium chloride shall be dissolved in 500 milliliters of water. Approximately 10 milliliters of concentrated aqueous ammonia shall be added and the resultant solution allowed to stand overnight. It shall be filtered if a precipitate appears. The solution shall then be made slightly acid with hydrochloric acid after which it shall be diluted to 1 liter and placed in a glass-stoppered bottle.

4.5.3.2 Procedure. A 20 gram sample of the anti-icing and deicing-defrosting fluid, weighed to the nearest 0.01 gram, shall be diluted with 100 milliliters of distilled water. Ten milliliters of a mixture of equal parts by volume of concentrated hydrochloric acid and water and 30 milliliters of the reagent prepared in accordance with 4.5.3.1 shall be added to the diluted sample. Concentrated aqueous ammonia shall then be added until the solution is neutral to methyl red indicator. The solution shall be stirred for 5 minutes and as stirring is continued, an additional 15 milliliters of aqueous ammonia shall be added. The solution shall then be allowed to stand for 4 hours or longer after which it shall be filtered and the magnesium pyrophosphate precipitate ignited in a weighed platinum crucible at 1000°C to 1050°C (1832°F to 1922°F) until constant weight is reached. The dibasic potassium phosphate content shall be computed as follows:

$$\text{Percent dibasic potassium phosphate content} = \frac{1.565 \times M}{W} \times 100$$

where

M = mass of the magnesium pyrophosphate precipitate in grams.
W = mass of the sample in grams.

4.5.4 Sodium di-(2-ethylhexyl) sulfosuccinate content.

4.5.4.1 Reagents. The following reagents shall be used in the determination of the sodium di-(2-ethylhexyl)sulfosuccinate content of the anti-icing and deicing-defrosting fluid:

a. Standard sodium di-(2-ethylhexyl) sulfosuccinate solution prepared by transferring 0.8 gram of pure sodium di-(2-ethylhexyl) sulfosuccinate, weighed to the nearest 0.1 mg, to a 250 milliliter glass-stoppered volumetric flask and diluting to the mark with distilled water. This solution shall be agitated (a mechanical shaker may be used) until complete solution is effected. Solutions over two weeks old shall be discarded.

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b. Methylene blue chloride solution prepared by dissolving 0.050 ± 0.005 gram of chemically pure (CP) methylene blue chloride in 1 liter of distilled water. Carefully add 10 milliliters of concentrated CP sulfuric acid and 50 grams of anhydrous sodium sulfate. Mix thoroughly to effect complete solution.

c. 0.005N cetyl pyridinium bromide prepared by dissolving 2.5 grams of cetyl pyridinium bromide in 1 liter of distilled water and filtering the solution.

4.5.4.2 Procedure. One hundred and fifty grams of anti-icing and deicing-defrosting fluid shall be weighed by difference in a 250 milliliter volumetric flask. The mass shall be determined to the nearest 0.1 gram. The flask shall be filled to the 250 milliliter mark with distilled water and the solution mixed thoroughly. A 10 milliliter aliquot of the anti-icing fluid solution and a 10 milliliter aliquot of the standard sodium di-(2-ethylhexyl) sulfosuccinate solution shall be transferred to separate 100 milliliter oil sample bottles. Twenty milliliters of the methylene blue chloride solution and twenty-five milliliters of CP chloroform shall be added to each bottle. The bottles shall be stoppered and shaken vigorously for several seconds. The contents of each bottle shall then be titrated with 0.005N cetyl pyridinium bromide in 1.0 milliliter portions, with vigorous shaking of the bottle after each addition, until the blue color in the chloroform (lower) layer begins to migrate to the upper layer. The titration shall then be continued drop by drop until the color intensities of both layers match exactly when viewed in transmitted light. The sodium di(2-ethylhexyl) sulfosuccinate content shall be computed as follows:

$$\text{Percent sodium di-(2-ethylhexyl) sulfosuccinate content} = \frac{W_1 \times T_2}{W_2 \times T_1} \times 100$$

where

W_1 = mass of sodium di-(2-ethylhexyl) sulfosuccinate used for standard solution.
W_2 = mass of anti-icing and deicing-defrosting fluid used fof solution.
T_1 = ml of cetyl pyridinium bromide solution required by the standard solution aliquot.
T_2 = ml of cetyl pyridinium bromide solution required by the anti-icing fluid solution.

4.5.5 Sodium salt of tolyltriazole content. A contractor's notarized certificate of compliance signed by a responsible official of the company is acceptable for the content of the sodium salt of tolyltriazole (see 4.2).

4.5.6 Alkaline earths. Ten milliliters of the anti-icing and deicing-defrosting fluid shall be placed in a 30-milliliter test tube. The fluid shall be made alkaline to litmus with ammonium hydroxide solution after which shall be added 5 milliliters of reagent grade ethyl alcohol (95 percent). Five milliliters of 0.5N ammonium oxalate shall then be added and the solution visually examined for evidence of precipitation. No immediate precipitate shall form.

4.5.7 Chlorides.

4.5.7.1 Type I. Ten milliliters of the anti-icing and deicing-defrosting fluid shall be placed in a 30-milliliter test tube. Ten milliliters of distilled water shall be added and thoroughly mixed with the fluid. Ten drops of concentrated nitric acid shall be added, the mixture thoroughly agitated and then filtered. Ten drops of a 3 percent aqueous solution of silver nitrate shall be added to the filtrate and the mixture allowed to stand for 30 minutes. No precipitate shall settle out within 30 minute after the addition of the silver nitrate. A slight turbidity shall not be cause for rejection.

4.5.7.2 Type II. Place 10 milliters of the anti-icing and deicing-defrosting fluid in a 30-milliliter test tube. Add 10 milliters of distilled water and mix. Add 10 drops of concentrated nitric acid, agitate the mixture, and add 2 milliliters of a 3 percent aqueous solution of silver nitrate. Filter and discard the filtrate. Wash the residue with concentrated ammonium hydroxide, recover the filtrate and acidify with concentrated ntiric acid. No precipitate indicates the absence of chlorides. A slight turbidity is allowed.

4.5.8 Corrosiveness.

4.5.8.1 Test panels. Test specimens shall consist of 1 by 6 inch panels of the following metals: aluminum alloy conforming to QQ-A-250/4 and anodized to conform to MIL-A-8625, type I or II; clad aluminum alloy conforming to QQ-A-250/13; clad aluminum alloy conforming to QQ-A-250/5; magnesium alloy conforming to QQ-M-44,cleaned and treated in accordance with MIL-M-3171; type III titanium alloy, 6Al-4V, conforming to MIL-T-9046; polished aluminum alloy conforming to QQ-A-250/4; and steel conforming to MIL-S-7952 cadmium plated to conform to QQ-P-416. The panels, prior to being subjected to test, shall be cleaned by boiling for 1 minute in CP isopropyl alcohol and 1 minute in CP mineral spirits.

4.5.8.2 Procedure. Five hundred milliliters of a 20 percent by volume solution of the anti-icing and deicing-defrosting fluid in distilled water shall be placed in a 1000-milliliter tall-form beaker. The panels described above shall then be placed on end in the solution, without touching each other, and allowed to stand for 24 hours at a temperature of 25°C ± 5°C (77°F ± 9°F). Wetting of the upper of the panels shall be avoided. After the 24 hour immersion, the panels shall be removed and allowed to air dry in an upright position for 3 hours. The panels shall then be re-immersed in the solution for 1 minute, removed and allowed to air dry for 24 hours. The panels shall be rinsed and then visually examined for corrosion by comparing the unexposed surfaces of the panels with the surfaces previously immersed.

4.5.9 Flash point. The flash point shall be determined in accordance with ANSI/ASTM D 92-78, except that the fire point need not be determined.

4.5.10 Pour point. The pour point of the fluid and of a 70 percent aqueous solution of the fluid, prepared in accordance with ANSI/ASTM D 1176-71, shall be determined in accordance with ANSI/ASTM D 97-66, except that the cloud point need not be determined.

4.5.11 Specific gravity. The specific gravity of the fluid shall be determined in accordance with ANSI/ASTM D 1122-58.

4.5.12 Color (type I only). A stock solution shall be prepared as follows: Dissolve 1.245 grams of potassium chloroplatinate (containing 0.5 gram of platinum) and 1.000 gram of crystallized cobaltous chloride ($CoCl_2.H_2O$) in distilled water with 100 milliliters of concentrated hydrochloric acid. Dilute to 1 liter with distilled water. The standard color solution shall be prepared by diluting 3 milliliters of the stock color solution to 100 milliliters with distilled water. The color shall be determined by transferring 100 milliliters of the fluid and 100 milliliters of the standard color solution to matched tall-form Nessler tubes and comparing by viewing vertically down through the tubes against a white background.

4.5.13 Ether and acetate solvents. A contractor's notarized certificate of compliance signed by a responsible official of the company shall be acceptable for these characteristics (see 4.2).

5. PACKAGING

5.1 Preservation-packaging. Preservation-packaging shall be level A or Commercial, as specified (see 6.2).

5.1.1 Level A. Unless otherwise specified, the anti-icing and deicing-defrosting fluid shall be furnished in 5-gallon or 55-gallon containers, as specified (see 6.2). The 5-gallon container shall conform to type I, class 3 (screw-cap closure) of PPP-P-704. The 55-gallon container shall be a closed top drum conforming to type I or type II of PPP-D-729.

5.1.2 Commercial. The anti-icing and deicing-defrosting fluid shall be packaged in specified quantities in a manner that will afford adequate protection against deterioration or physical damage during shipment from the supply source to the first receiving activity and for a minimum of 30 days storage, utilizing containers required by the Code of Federal Regulations, Title 49, Parts 100-199.

5.2 Packing. Packing shall be level A, B, or Commercial, as specified (see 6.2).

5.2.1 Levels A and B. The anti-icing and deicing-defrosting fluid, packaged in accordance with 5.1.1, does not require any overpacking. Standard 4 way entry pallets are required for handling by mechanical equipment.

5.2.2 Commercial. The anti-icing and deicing-defrosting fluid, packaged as specified in 5.1.2, shall be packed in shipping containers in a manner that will afford adequate protection, at the lowest rate, against damage during direct shipment from the supply source to the first receiving activity. The containers shall conform to the rules and regulations of the mode of transportation utilized and when applicable, comply with the National Motor Freight Classification or the Uniform Freight Classification Rules.

5.3 Marking. In addition to any special markings required by the contract, each container shall be marked in accordance with MIL-STD-129 plus the following:

CAUTION

DO NOT TAKE INTERNALLY.
AVOID BREATHING VAPOR.
KEEP AWAY FROM FIRE, SPARKS AND
  POWERFUL OXIDIZING MATERIALS.
STORE IN A COOL PLACE.
KEEP CONTAINER CLOSED.
MINIMUM FLASH POINT - 101.7°C (215°F).

6. NOTES

6.1 Intended use. The anti-icing and deicing-defrosting fluids covered by this specification are intended for use in removing frost and ice from the surface of parked aircraft and to prevent the formation of ice and frost on such surfaces. Type I is for Air Force use.

6.2 Ordering data. Acquisition documents should specify the following:

a. Title, number and date of this specification
b. Type required (see 1.2)
c. Type and size of container (see 5.1.1)
d. Quantity in gallons
e. Level of packaging and packing required (see 5.1 and 5.2)
f. Reduced testing and examination when specified (see 4.4.1)

6.3 Batch. A batch is defined as that quantity of material which has been manufactured by some unit chemical process and subject to some physical mixing operation intended to make the final product substantially uniform.

6.4 Precautionary handling instructions. The anti-icing and deicing-defrosting fluids furnished under this specification are mildly toxic and contact with skin and eyes should be avoided. Prolonged exposure to concentrations exceeding 1000 parts per million parts of air should also be avoided. Although the fluid has a minimum flash point requirement of 101.7°C (215°F), it should be used with care when applied around heaters or engine exhausts.

6.5 Unit of purchase. The fluid covered by this specification should be purchased by volume, the unit being one U.S. Gallon at 25°C (77°F).

6.6 Cross-reference of classification. Type I is identical to the material furnished under MIL-A-8243B. Type II is a new formulation.

6.7 Changes from previous issue. Asterisks are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

Custodians:
Navy - AS
Army - EA
Air Force - 11

Review activities:
Army - AV
Air Force - 68
DSA - GS

User activities:
Navy - CG, MC

Preparing activity:
Navy - AS
(Project No. 6850-0602)

TABLE I. Composition.

Component (percent by weight)	Type I	Type II	Test paragraph
1, 2-glycols, minimum	88.0	88.0	4.5.1
Water	9.0 - 10.0	9.0 - 10.0	4.5.2
Dibasic potassium phosphate (K_2HPO_4), maximum	1.1	1.1	4.5.3
Sodium di-(2-ethylhexyl) sulfosuccinate (100% active)	0.45 - 0.55	0.45 - 0.55	4.5.4
Sodium salt of tolyltriazole	-	0.50 - 0.60	4.5.5

TABLE II. Chemical and physical properties.

Characteristics	Requirements	Test paragraph
Alkaline earths	None allowed	4.5.6
Chlorides	None allowed	4.5.7
Corrosiveness	1/	4.5.8
Flash point °C (°F), min.	101.7 (215)	4.5.9
Pour point °C (°F):		4.5.10
Undiluted	-54 (-65)	
70 percent aqueous solution	-54 (-65)	
Specific gravity (undiluted material) at 15.6°/15.6°C (60°/60°F)	1.100 to 1.106	4.5.11
Color (type I only)	Not darker than standard	4.5.12
Ether	None allowed	4.5.13
Acetate solvents	None allowed	4.5.13

1/ The metal specimens shall show no trace of corrosion when tested as specified in 4.5.8. Slight discoloration of the cadmium plated panels shall not be considered objectionable.

TABLE III. Quality conformance tests.

Inspection tests	Requirement paragraph	Test method paragraph
1, 2-glycols	3.2	4.5.1
Water	3.2	4.5.2
Dibasic potassium phosphate (K_2HPO_4)	3.2	4.5.3
Sodium di-(2-ethylhexyl) sulfosuccinate (100 percent active)	3.2	4.5.4
Sodium salt of tolyltriazole	3.2	4.5.5
Alkaline earth	3.3	4.5.6
Chlorides	3.3	4.5.7
Corrosiveness	3.3	4.5.8
Flash point	3.3	4.5.9
Pour point	3.3	4.5.10
Specific gravity	3.3	4.5.11
Color	3.3	4.5.12
Ether	3.3	4.5.13
Acetate solvents	3.3	4.5.13

TABLE IV. Examination of end item.

Examine	Defect
Material	Not as specified.
Appearance	Presence of foreign matter.

TABLE V. Net content.

Lot size (containers)	Sample size (containers)
Up to 50	5
51 - 500	7
501 - 35,000	8
3,500 and over	11

TABLE VI. Packaging inspection.

Examine	Defect
Container	Evidence of leakage, bulging or distorted.
Marking	Missing, incorrect, illegible. Improper size, location or method of application.

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DOCUMENT IDENTIFIER *(Number)* AND TITLE

MIL-A-8243C ANTI-ICING AND DEICING-DEFROSTING FLUIDS

NAME OF ORGANIZATION AND ADDRESS OF SUBMITTER

☐ VENDOR ☐ USER ☐ MANUFACTURER

1. ☐ HAS ANY PART OF THE DOCUMENT CREATED PROBLEMS OR REQUIRED INTERPRETATION IN PROCUREMENT USE? ☐ IS ANY PART OF IT TOO RIGID, RESTRICTIVE, LOOSE OR AMBIGUOUS? PLEASE EXPLAIN BELOW.

A. GIVE PARAGRAPH NUMBER AND WORDING

B. RECOMMENDED WORDING CHANGE

C. REASON FOR RECOMMENDED CHANGE(S)

2. REMARKS

SUBMITTED BY *(Printed or typed name and address — Optional)*

TELEPHONE NO.

DATE

DD FORM 1 OCT 76 1426 EDITION OF 1 JAN 72 WILL BE USED UNTIL EXHAUSTED.

FILE **T.O. 42C-1-2**

TECHNICAL MANUAL

ANTI-ICING, DE-ICING AND DEFROSTING OF PARKED AIRCRAFT

THIS PUBLICATION SUPERSEDES T. O. 42C-1-2, DATED 15 NOVEMBER 1965 AND SAFETY SUPPLEMENT T. O. 42C-1-2SS-1, DATED 4 APRIL 1974.

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SECTION I

INTRODUCTION

1-1. PURPOSE.

1-2. The purpose of this technical manual is to provide instructions for the use and application of anti-icing and deicing defrosting fluid, Specification MIL-A-8243, for snow, frost, and ice prevention and removal from parked aircraft. All aircraft operating under Arctic or subfreezing weather conditions are subject to snow, frost, and ice accumulating on the surfaces while the aircraft is on the ground. To prevent heavy accumulations and to promote speedy, efficient and economical removal of accumulated snow, frost, and ice from aircraft surfaces, the procedures set forth in this manual will be followed.

1-3. GENERAL.

1-4. A protective coating of unheated, undiluted anti-icing and de-icing defrosting fluid will prevent frozen accumulations from forming on surfaces of aircraft if applied before such freezing conditions begin and if applied as often as necessary during the precipitation. Any frost or thin layer of ice that does form can be easily removed by application of additional fluid. On aircraft for which covers are available, a protective coating of the fluid applied before installation of covers will permit easy removal with a minimum of sticking of the covers.

1-5. Where frozen deposits of snow, frost, or ice are present on the surface, they can be removed rapidly and economically by using a heated solution of the diluted fluid. After removal, a coating of cold, undiluted fluid applied to the surface will prevent frozen accumulations from forming. During severe weather conditions, more than one protective coating may be required to keep the aircraft clear of ice and snow.

1-6. FLUID.

WARNING

Extreme caution must be exercised in the use of glycol-water solutions (including MIL-A-8243 anti-icing/deicing/defrosting fluid) in and around aircraft having silver or silver-coated electrical/electronic circuitry. Rapid oxidation and fire can occur when glycol-water solutions come in contact with and short across bare or defectively insulated silver or silver-coated electrical circuits such as wiring, switches, circuit breakers, etc, which are carrying positive direct current (dc).

1-7. Anti-icing and de-icing defrosting fluid, Specification MIL-A-8243, is composed basically of a mixture of ethylene glycol - propylene glycol in a 3:1 mixture and a corrosion-inhibiting compound and a wetting agent.

SECTION II

EQUIPMENT

2-1. USE OF EQUIPMENT.

2-2. Suitable spray equipment should be used as the application of de-icing fluids is best accomplished by spraying on surfaces. The spraying units, NSN 1730-00-140-3510 (small de-icer unit), NSN 1730-00-529-8885, NSN 1730-00-665-2196, NSN 1730-00-152-2788, or NSN 1730-00-874-9617 may be used for de-icing most trainer, fighter, cargo and bomber type aircraft. Large aircraft such as the C-5A may also be serviced with spraying equipment such as NSN 1730-00-168-5959, Servicing Platform, Type A/S32M-13, as detailed in 35D34-6 Series technical manuals. The spray shall be fine enough to prevent wasting the fluid. A fine fanshaped pattern is recommended. It should not be applied in a solid stream. This technical order will not be considered as authority to obtain equipment other than authorized in the applicable Equipment Components List.

2-3. If the equipment referenced in paragraph 2-2. is not available, cleaning and/or other decontaminating equipment may be modified to spray de-icing fluids. The spray guns provided on this equipment may be used as they are, but better spray coverage can be obtained if they are modified slightly. A common garden hose nozzle will give satisfactory results in accumulation removal if the solid stream is used. This nozzle can also be used to apply the protective coating of de-icing fluid if the fine conical spray is used.

2-4. APPLICABLE SPRAY EQUIPMENT TECHNICAL MANUALS.

2-5. The 35D34 and 35E17 Series technical manuals should be consulted for purposes of identifying parts, acquiring parts, and for emergency repair and fabrication of any spraying component.

2-6. Steam cleaners can be utilized to heat solutions of de-icing fluid to approximately 120°F ± 10°F, (49°C ± 5°C). Hot water could also be secured from the base hot water system and mixed with the de-icing fluid to eliminate the need for using the steam cleaner.

SECTION III

APPLICATION

3-1. GENERAL.

WARNING

Extreme caution must be exercised in the use of glycol-water solutions (including MIL-A-8243 anti-icing/deicing/defrosting fluid) in and around aircraft having silver or silver-coated electrical/electronic circuitry. Rapid oxidation and fire can occur when glycol-water solutions come in contact with and short across bare or defectively insulated silver or silver-coated electrical circuits such as wiring, switches, circuit breakers, etc, which are carrying positive direct current (dc).

3-2. Where hangers, covers, or equipment for heating the de-icing fluid-water solutions are not available, the preventive spraying method will be utilized to maintain stand-by and alert aircraft in a state of readiness. The preventive spraying method is the application of cold undiluted Specification MIL-A-8243 fluid on the surface to be protected in a quantity sufficient to thoroughly wet the area without excessive drainage.

3-3. DILUTION OF FLUID.

3-4. Diluted solutions of deicing fluid shall be formulated and used according to the known or anticipated ambient temperature. Specification MIL-A-8243, anti-icing and deicing defrosting fluid shall be mixed in accordance with ambient temperatures and dilution ratios as specified in Figure 3-1.

For Ambient Temperature of Fahrenheit Degree	Percent Fluid by Volume	Percent Water by Volume	Approximate Freezing Point of Mixture Fahrenheit Degree
Plus 30° and above	20	80	Plus 10°
Plus 20°	30	70	0°
Plus 10°	40	60	Minus 15°
0°	45	55	Minus 25°
Minus 10°	50	50	Minus 35°
Minus 20°	55	45	Minus 45°
Minus 30°	60	40	Minus 55°

Figure 3-1. Recommended Fluid Dilutions

3-5. DETERMINATION OF FREEZING POINT.

3-6. Prior to use, to avoid any operational difficulty with equipment such as freezing of the fluid-water mixture, the freezing point of the mixture should be checked with a hydrometer by carefully adhering to the following procedure.

a. The fluid mixture must be at a temperature between 10° C (50° F) and 65° C (150° F) when readings are made.

b. Fill and empty hydrometer several times with fluid mixture to equalize the temperatures of the hydrometer and the mixture.

c. Draw liquid into hydrometer until the float moves freely and surface of liquid can be seen.

d. Hold the hydrometer in a vertical (straight up and down) position.

e. Read the number of the float line which is nearest to (above and below) the surface of the liquid. Find this same number at either the bottom or the top of the main chart (table) in the barrel of the hydrometer. Immediately read the thermometer. Read the percent of glycol indicated in the square at the intersection of the vertical column containing the observed float reading with a horizontal line leading around the barrel from the top of the red thermometer liquid. To determine the freezing point of the liquid, consult the small table above the main chart, after determining the percent glycol as just outlined.

3-7. PREVENTION OF DEPOSITS.

3-8. FROST. A satisfactory procedure for the protection of aircraft from frost is to apply a layer of unheated, undiluted fluid, Specification MIL-A-8243, to the aircraft surfaces after the last flight of the day or as close to midnight as possible, whichever is later. This should permit early morning departure without further fluid application. The length of time that the aircraft will be protected by a single coat of fluid is dependent upon climatic conditions. In the state of Washington, for example, under conditions where as much as one-quarter inch of frost will normally accumulate, a single protective coat applied between 2000 and 2400 hours will keep the surfaces free and clear of frost and the aircraft can take off without further de-icing.

3-9. FREEZING RAIN. Fluid, Specification MIL-A-8243, will protect aircraft surfaces as long as it remains on the surfaces. However, a freezing rain will tend to wash the surfaces clean of fluid as well as dilute the fluid to the point where ice is formed as if no fluid had been present. The amount of protection afforded by this fluid will be dependent upon the amount of freezing rain.

a. On aircraft for which covers are available, a coating of fluid applied before the covers are installed will prevent the covers from freezing to the aircraft surfaces and also make the job of removing these covers much easier. However, care should be taken to insure that only the minimum amount of rain is allowed to blow under the covers or dilution of the fluid will allow freezing to occur.

b. On larger aircraft where wing covers are not available, the best method of prevention is to keep the surfaces wet with fluid, Specification MIL-A-8243. As long as this fluid remains on the surface protection is afforded. Since rain will in some period of time dilute the fluid and render it ineffective for preventing ice from forming, protection must be maintained during precipitation by continual spraying of the fluid. If the weather conditions are such that it is impossible to prevent ice formation, removal should be accomplished as recommended in paragraph 3-14.

3-10. SNOW. If snow is expected, wing and tail covers should be used if possible. Fluid, Specification MIL-A-8243, should not be used for a protective coating when snow is predicted, except in conjunction with the installation of covers. If attempts are made to use this fluid to prevent the accumulation of snow, a frozen deposit which is difficult to remove will be encountered. The fluid is diluted by the melting snow forming a slush mixture which will freeze in place. The use of covers, after the aircraft surfaces have been coated with fluid, will keep the snow from forming directly on the aircraft and will permit rapid removal of the covers and snow with a minimum of effort. If covers are not available, the best method of prevention against heavy accumulations of snow on the aircraft is constant removal by brushing or sweeping during the snowfall, or by blowing heated air on aircraft surfaces as authorized in T. O. 35E17-6-11.

3-11. REMOVAL OF DEPOSITS.

3-12. Where hangars and covers cannot be used for prevention of frozen formations on the aircraft, but equipment for heating Specification MIL-A-8243 fluid-water solutions is available, removal by hot diluted de-icing fluid solutions will be used in place of preventive spraying. Accumulations should be allowed to form and be removed as explained below just after each precipitation or just before each flight, whichever is most practicable or compatible with the operational mission of the aircraft being de-iced.

3-13. REMOVING FROST. Frost can easily be removed by spraying with cold undiluted fluid, Specification MIL-A-8243, or by spraying with hot diluted fluid, Specification MIL-A-8243.

3-14. REMOVING ICE. The use of fluid, Specification MIL-A-8243, water mixture heated to 180° - 200°F (82°-93°C) will speed up ice removal from aircraft surfaces. The mixture should be made in accordance with Figure 3-1. Application of hot diluted fluids is best accomplished by spraying a solid stream of fluid (not over 15 gallons per minute) to flood the surface of the ice and to wash the loose pieces of ice from the wing. A sufficient amount of heated fluid must be kept on the ice to keep the liquid layer from freezing. The heated fluid should be applied at pressures as high as possible, but not over 100 pounds per square inch on fabric surfaces nor over 300 pounds per square inch on metal surfaces. Particular attention must be directed to clearing all ice from the hinges of control surfaces. Existing cleaning equipment or larger mobile spraying equipment may be modified to incorporate a means of heating the fluid.

3-15. In the event a hot de-icing fluid solution cannot be used and it is absolutely necessary to remove the ice from the aircraft, cold undiluted de-icing fluid will do the job. The fluid should be sprayed to assure complete coverage without excessive drainage at 15-minute intervals. Removal of heavy accumulations of ice with cold de-icing fluid is an expensive and slow operation and should be used only as a last resort when other means are not available.

CAUTION

Extreme care shall be exercised at all times to prevent any damage to the aircraft surfaces. Sharp instruments such as picks, knives, or screw drivers will not be used to loosen the ice formation.

3-16. REMOVING SNOW. De-icing fluids should not be used to remove heavy accumulations of snow. The snow absorbs wasteful amounts of the fluid forming a slush which is very difficult to remove and in time (depending upon the ambient temperature) will refreeze. The slush will get into the control surface hinges and freeze, causing additional unnecessary difficulty. Generally, snow will be removed by removing the covers or by brushing or sweeping it off the aircraft.

3-17. In an emergency where the aircraft must get off the ground as quickly as possible, thin layers of snow can be removed using heated, diluted fluid as described in paragraph 3-4. If sufficient fluid is applied, the combination of the heat from the fluid and the force of the stream will permit the removal of slush as it is formed without refreezing. The quantity of heated fluid required for snow removal is prohibitive. If an emergency does not exist or if heavy snow accumulations are encountered, as much snow as possible should be brushed or swept off the aircraft surfaces. Usually after removing the snow, a layer of very rough ice remains on the surface. This frozen crust can be quickly removed using the heated, diluted, de-icing fluid solutions.

SECTION IV

CHARACTERISTICS AND PRECAUTIONS

4-1. SAFETY PRECAUTIONS.

WARNING

Anti-icing and de-icing defrosting fluid, Specification MIL-A-8243, is mildly toxic and contact with skin or eyes should be avoided. Prolonged exposure to concentrations exceeding 1000 parts per million parts of air should be avoided. The fluid may possibly flash at temperatures above 200°F and proper precautions should be taken to insure that the fluid is kept away from all sparks, fire, and oxidizing agents. Operators should stay on the windward side during spray or brush application. Adequate eye protective equipment should be worn by all personnel engaged in the application of these fluids. Deicing fluids containing ethylene glycol have been found to cause severe spalling of portland cement concrete pavements. This damage may be prevented or minimized by treating such pavements prior to exposure with light seal coats of emulsified linseed oil. Asphalt pavements do not require protective coatings and linseed oil will not be applied to these pavements.

Prior to LOX servicing, the fluid will be removed from areas adjacent to the LOX filter and overflow tubes by flushing or wiping methods. Contact of fluid with LOX, a powerful oxidizing agent, may result in a fire or explosion. Although the fluid's flash point is above 93°C (200°F), the fluid should be used with care when sprayed around heater or engine exhausts. Special care shall be exercised to prevent the excessive use of fluid around cabin heater and/or ventilator air intake ducts. This precaution is essential to minimize the possibility of toxic fumes entering the cabin or cockpit during taxi prior to takeoff.

Extreme caution must be exercised in the use of glycol-water solutions (including MIL-A-8243 anti-icing/deicing/defrosting fluid) in and around aircraft having silver or silver-coated electrical/electronic circuitry. Rapid oxidation and fire can occur when glycol-water solutions come in contact with and short across bare or defectively insulated silver or silver-coated electrical circuits such as wiring, switches, circuit breakers, etc, which are carrying positive direct current (dc).

CAUTION

The linseed oil treatment described below should not be used on surfaces where liquid oxygen (LOX) spills are likely to occur. Emulsified linseed oil consists of raw linseed oil (48% by volume) dispersed in water (in alkaline solution). It can be procured through local paint manufacturers. Equipment for dispensing the linseed oil in water is not normally available at Air Force bases. Pavement surfaces should be cleaned and dry at time of application. Ambient temperature should be above 60°F. The amount of application is approximately 15 to 20 square yards per gallon. The emulsified linseed oil should be applied thick enough to fill the pores in the pavement but not thick enough to leave a visible coating after a 10 to 20 minute soak time. Better penetration will be obtained if the liquid is heated to and applied at a temperature of 100° to 140°F.

TABLE 4-1. PRECAUTIONARY DATA

DO	DON'T
1. Remove fluid from around LOX filler and overflow tubes prior to servicing aircraft with LOX.	1. Apply fluid when LOX carts are in vicinity of aircraft.
2. Position stabilizers and elevators so that liquid will be drained from surface.	2. Apply fluid by spray method unless all personnel are clear of spray areas.
3. Remove ice from leading edge first and then move progressively aft.	3. Use fluid for removal of heavy snow or ice deposits.
4. Remain on windward side during spray or brush applications.	4. Use water to wash snow off aircraft.
5. Wear adequate eye protection when applying fluid.	
6. Operate spray boom slowly and cautiously. (Boom operators should be thoroughly trained in their job).	
7. Re-apply fluid as needed during severe weather or when takeoff is delayed.	
8. Use covers whenever possible.	
9. Inspect control surfaces for complete removal of ice, snow and slush.	
10. Manually check control surfaces through their full range of travel to insure freedom of movement.	

SECTION V

SUPPLY DATA

5-1. The following material and equipment will be requisitioned as necessary:

TABLE 5-1. SUPPLY DATA

STOCK NUMBER	NOMENCLATURE	SOURCE
6630-00-247-2968	Tester, Anti-freeze Solution	S9M
6850-00-558-1248	Anti-Icing and De-icing Defrosting Fluid, 55-Gallon Drum, Specification MIL-A-8243	S9G
6850-00-582-4685	Anti-icing and De-icing Defrosting Fluid, Bulk, Specification MIL-A-8243	JBC
1730-00-529-8885	Spray Outfit - De-icing or Decontaminating Fluid, Specification MIL-S-4907	FPZ
1730-00-665-2196	Spray Outfit - De-icing or Decontaminating Fluid, MB-3	FPZ
1730-00-874-9617	Spraying Unit, Cleaning De-icing Decontaminating Fluid, AF/S32M1	FPZ
1730-00-140-3510	De-Icing Unit P/N 60148	FPZ
1730-00-076-6151	Spraying Unit P/N 336-H-1000-40-13 (Mfg, John Bean)	FPZ
1730-00-152-2788	Spraying Unit, AF/S32M-1 (Mfg, Reading Techmatic)	FPZ
1730-00-168-5959	Servicing Platform Type A/S32M-13 (Mfg, Calavar Corp)	FPZ

5-2. EMERGENCY USE FORMULATION. Anti-icing, de-icing, and defrosting fluid, Specification MIL-A-8243, is procured and stocked for world-wide issue; but in case of local shortage, this material may be compounded in accordance with the following:

Add 2-1/2 pounds of Aerosol OT (100 percent) to 10 gallons of propylene glycol. Heat to dissolve. Add 35 gallons of ethylene glycol and a solution 5 pounds of dibasic potassium phosphate ($K_2 HPO_4$) in 5 gallons of water.

Mr. GORE. Chairman Glickman is on his way back, and we will get started in a few minutes. If you will bear with us, we will recess for a brief period.

[Recess taken.]

Mr. GLICKMAN. Let us get back on the record. I apologize, but most of you know what life is like around here.

I would like to ask a question of General Ralph, because I could not help but be intrigued with your comments on the FAA's budget cuts, specifically the R. & D. budget. I would like you to comment on the difference between your testimony and Mr. Albrecht's testimony, because I think it is significant. You basically state that the FAA's efforts are at a virtual standstill, and maybe I am reading something into what you said. Mr. Albrecht clearly left the impression here that this was not true at all. That at least was my understanding. I think the implication from what I heard him say was that they had a reduction in fiscal 1982, but it was going to go up in fiscal 1983 to a level above what it was in fiscal 1981. I wonder if you could amplify on that.

General RALPH. I suppose your position depends upon where you are sitting at the time. The FAA technical center had a significant reduction in personnel in fiscal year 1981. They have a significant reduction in funding in fiscal year 1982. In building toward the capability to modernize the ATC system, the FAA is going to have to do additional significant research in systems and procedures for the new ATC system. The first of that money, hopefully, will appear in fiscal year 1983.

So my comments, I think, reflect circumstances that exist. We might argue whether or not I should use words like "dramatic" or "come to a virtual standstill," but there certainly has been a significant reduction in programs. There is a requirement for increased research programs to support the modernization of the ATC system, and I believe that it is a legitimate question to ask if the FAA is adequately funded to undertake these responsibilities.

Mr. GLICKMAN. Apparently then, what you are saying is that a big squeeze is going on: they are going to have to devote a lot of their dollars into the national airspace system, which then cannot be devoted into a multitude of other things.

General RALPH. Yes, aeronautical flight safety as opposed to ATC system safety.

Mr. GLICKMAN. I would like to ask a question of Captain O'Donnell. I do not think Mr. Gore got into the question of distance-to-go markers, and I think in your testimony as well as in your remarks you indicate that this is something you have been pushing for a long time. For the life of me, I cannot understand why we do not do this. There is virtually no or very little cost involved. I wonder if you could give me some idea why the FAA and/or airports have resisted distance-to-go markers?

Captain O'DONNELL. I think it is basically one thing: economics. Any place they can get out of spending money they will get out of it, and that includes the FAA and the airport operators themselves. I think it is a matter of priorities to the airport operators: they only have so much money, and they establish a priority. But I get concerned when they build expensive cocktail lounges and put big expensive monuments in the lobbies of the airports and do not give us basic safety items, such as the boards for runway-length remaining.

I would like to say one other thing that I did not cover earlier. We did receive a very positive response from NASA on that runway friction testing comparative system. The only thing is, although they are ready to correlate it and go forward with it, it is sitting over at the FAA and we are getting no response. It is hidden in one of the closets over at the FAA, and somehow it has to be shaken out of there. I think that is something we could have had 5 or 6 years ago, with the amount of research done on it. I would hope that this committee would push the FAA to ask, Where is it? If NASA is ready to go ahead with it and put that program together, why not go ahead and do it? It may have prevented the accident in Boston.

Mr. **Glickman**. I would like to talk about icing for a minute, not the generic icing research on the airplane in flight but icing on the ground and deicing. As you know, the NTSB has made some recommendations on deicing. Have either of you had a chance to review those recommendations, either from the pilot's point of view or the airline's point of view?

Captain **O'Donnell**. I have not reviewed the FAA's recommendations, but we have known for many, many years what basic anti-icing procedures you should be using. We know what deicing procedures should be used, and they are totally different. As I mentioned earlier, we have a copy of a report, and we will provide you with the title and the date so that the committee can get a copy of it. It was done in 1957 by the U.S. Air Force, and it was a complete, analytical study of deicing and how it should be done. It was updated again in 1976, and I heard the FAA this morning testify that they were not aware of any research done in this area. Those are the things that disturb us.

Mr. **Glickman**. General Ralph?

General **Ralph**. The NTSB sent a letter to the FAA, commenting on and including some recommendations on an interim basis as a result of the Palm 90 accident. The administrator forwarded, as I recall, almost in their entirety, the recommendations that the NTSB made.

The Air Transport Association was apprised of what they were doing. We took it upon ourselves, through our own channels, to telex all of our members, including both the NTSB comments and the FAA responses and bringing to everyone's attention the sensitivity and the necessity for abiding by good procedures in deicing.

Mr. **Glickman**. There seems to be no regularity in the issue whatsoever. In fact, if anything, that is one of the most incredible conclusions that has come out so far in the NTSB hearing. That is, in terms of the nature of the deicing material, the intensity, and/or percentage of mixture, and/or when or how or whom, there is little uniformity. As I said before, it is an issue that has completely fallen through the cracks: How do you deice an airplane and whose judgment is it? I would hope that the hearings could reach some sort of general conclusions or recommendations on how to resolve that issue.

Captain **O'Donnell**. Mr. Chairman, there was one point in the NTSB recommendations that we do not concur with, and that is to give somebody else—whether it is the air traffic controller or some maintenance person on the ground or somebody else—who goes out to the end of the runway and says whether or not it is OK to go ahead and take off or the ice is clear off your wing. That may be acceptable to some airline pilots in this country, but I know of 33,000 ALPA members to whom it is not acceptable.

Basically, if there is a question of ice on your aircraft, the pilot in command has the responsibility to take it back to the ramp and get out and inspect it. I heard it mentioned this morning about why people survive in the back of an airplane. We have yet to find a way to crash an airplane tail first, where the crew can survive. As long as the crew is going to get killed, we are going to make that final decision.

Sometimes airline pilots err, but we make a takeoff and landing roughly every 13 seconds around the clock in this country. So we have a pretty good safety record. I agree with General Ralph that we have the finest system in the world, and we are going to have errors. I think that is the question on human factors, that we have to define and determine why pilots make certain errors.

Mr. GLICKMAN. I just want to follow up with one final question. Dr. Roland will testify that the average pilot is not very susceptible to the caution "Be careful," and he indicates that more training is necessary. Now that is a kind of a generic question I am asking you. I wonder if you would comment on that.

Captain O'DONNELL. I would not agree with that conclusion. I do not know how many times he sat in the front of an airliner and pushed those throttles forward, but I have been flying for quite a few years, and I do not find pilots to be zealots or have the motivation to kill themselves.

I can remember many times I have taxied back to the ramp just because I did not like the way something looked. In the airlines in the early days—and I am sure it is occurring today in the deregulated environment—the chief pilot or somebody else would give you a jaundiced look: "Why in the hell did you come back? You just cost this company $400 or $1,000." Those pressures have existed in history past, and I would hope they would not return.

In fact, I testified against deregulation because I think we will return to a similar situation here in the next 10 or 15 years if the Government does not wake up. We are going to have a serious problem in this country, in a deregulated environment, with the economics of the industry the way they are today. When they start to cutback, they start cutting back on maintenance. I am not saying that they did it in the Air Florida situation, but they start having thinner solutions in the glycol and deicing. Every place you can cut back on, it will occur in the future.

Mr. GLICKMAN. It is obvious that the less glycol you put in the solution, the less it costs you; right?

Captain O'DONNELL. Exactly right. And if you taxi back from the end of the runway because you do not like the way the ice is forming or the snow is forming on your wing, it costs the company money.

I am not saying this is occurring today, because I do not think we have really flowed into the deregulated environment yet. We cautioned the Congress of the United States when they were talking about deregulation that we will return to that problem in the future, if the Congress and the Government do not do something.

Mr. GLICKMAN. I do not think you are going to find very many Members of Congress wanting to go back to that environment.

Captain O'DONNELL. I find we fly with the Members quite a bit, and that is why I hope you will not allow it.

Mr. GLICKMAN. Thank you.

Mr. Dunn?

Mr. DUNN. I am a little surprised at your strong statement, Captain, in regard to my suggestion of having someone at the end of the runway. You unequivocally state that 33,000 airline pilots would be opposed to that idea. How do those 33,000 pilots sitting in that cockpit know whether there is ice on the wings or not?

Captain O'DONNELL. Generally what happens, Congressman Dunn, is that when you are in the snow, ice, freezing rain, sleet, or fog, you know what the temperatures are, the dew points are. You know exactly the condition of the aircraft, whether it is cold-soaked or not. The pilots are required by law to take a walk around that aircraft at the gate, before they climb on board, and you look at the surfaces. It is not so much the leading edge, as it is in some of our aircraft, it is the fillets, where the wings tie on to the fuselage. You get an awful lot of turbulence, stall, and prestall warnings out of that environment, more than we do the wing leading edge itself.

If I taxi out, and I have to sit out there for 25 or 30 minutes, and I have been glycoled at the gate, in the old days I would have my flight engineer look at the wing to make sure it was clear of snow. If he did not like the looks of it, he would question it. I would set the parking brakes, the copilot would sit there with the brakes on, and I would go back and look at it. If I did not like it, and I have on numerous occasions, I would taxi back to the ramp or taxi back to the hangar full of passengers, because in my judgment it was not good to take off.

I do not want somebody sitting at the end of the runway telling me, "It's OK to go." If I do not think it is OK to go, I am not going to go. And if I take off on his say so, who is responsible: He or I?

Mr. DUNN. You just spent 3 minutes not answering my question. I will ask it once again. How do you unequivocally, 100 percent, know from sitting in that cockpit, unless some of the time you do some of the things you talked about—which does not happen 100 percent of the time; you and I both know that—how do you know there is no ice on those wings? You do not.

Captain O'DONNELL. No, you do know. You are paid enough to know. You go back and look at the wing if you have a question in your mind.

Mr. DUNN. That does not happen 100 percent of the time.

Captain O'DONNELL. To have a question in your mind?

Mr. DUNN. Right.

Captain O'DONNELL. I would say it would happen 100 percent of the time in the years I have flown. I have 17,000 hours of flight time as a commercial airline pilot. And any time I had the slightest question on the condition of that wing, I would go back and look at the wing.

Mr. DUNN. The fact is that in the conditions that make for icing, the pilots do not get out of that seat and check the condition of the wings 100 percent of the time. You and I both know that is true.

Captain O'DONNELL. That is because they know by experience these conditions, the visual cues they have around them, whether or not they are accumulating ice.

Mr. DUNN. I understand experience, and you have a lot more hours than I do. Also, you and I both know that every single day, as it affects the condition, that wing is different.

Captain O'DONNELL. Oh, no question about that.

Mr. DUNN. That was not the question I wanted to ask you, even though we disagree on that one.

You touched in your testimony on the question of human factors. You say it is probably the most important. I would agree with you, particularly when it comes to general aviation accidents. The bottom line of almost every FAA accident report ends with some line like, "Pilot continued flight into conditions beyond his capability, resulting in disorientation."

You allude to it somewhat when you say, "Not just one element but a combination of factors in a complex sequence led to accidents." I define that quite simply as the domino theory, that myself, as a single pilot in a twin engine can handle maybe three things, but you fellows with your equipment can handle maybe five things before we are really in trouble.

But nevertheless, in this area of research on human factors, I do not think we spend enough research dollars explaining to pilots that domino theory, talking about it, and letting them make a decision that maybe ice by itself, maybe length of runway by itself, or maybe slush on the runway by itself, or maybe an engine gage that is not working completely by itself is not a problem; but all added together, they can be.

How do we get more research in that area? You make the statement that "some airlines are going along with it." You say, "However, not all carriers have done so." How does this committee get all carriers to get involved in that. It is a terribly complex area: you said that, and I agree.

Captain O'DONNELL. I think it goes beyond that. The point very simply is this. We have had a long record of accident determinations of probable cause by the NTSB and by other Government agencies over the years. They come to the bottom line and say, "In our judgment, these three things occurred, and therefore the probable cause of the accident was pilot error." I agree with what you just said: it may have been five or six other things that nobody ever knew about.

What we are saying is, let us go to these accidents that are occurring. Let us somehow or the other, on a cooperative basis, sit down with the people involved—I am talking about the pilots, the controllers, the management. We need to do this on a cooperative basis—because if you do not do it that way you will never find out a thing—and find out why a pilot, a controller, or whoever did a certain thing. We ought to go back in his mind to find out why he did it. If you do not get into his mind, you will never find out the true probable cause.

NASA recommended this in years past. The only way you can do that is on a cooperative basis with the people involved in these accidents. Have the Government do it in a nonadversary position. We may prevent one accident in the next 10 years. That is what we are saying: human factors studies and evaluations have to go far beyond where they are now. The FAA too frequently uses a time/motion study to determine human factors and workloads. That is lunacy. That is not telling you what is going through that man's mind. That is what we are talking about, sir.

Mr. DUNN. Thank you.

Mr. GLICKMAN. We thank you for your testimony and your candid remarks.

Mr. GLICKMAN. Has Mr. Joseph Stiley arrived, or anybody representing him?

[No response.]

Our next panel of witnesses consists of Dr. Harold Roland, University of Southern California, and Dr. C. O. Miller, a safety consultant formerly with the NTSB.

We thank you both for appearing here. We are sorry for the delays and your having to sit here and wait. Your entire statement will appear in the record, so you may feel free to summarize in any way you deem appropriate. We will start with Dr. Roland.

STATEMENT OF DR. H. E. ROLAND, INSTITUTE OF SAFETY SYSTEMS MANAGEMENT, UNIVERSITY OF SOUTHERN CALIFORNIA

Dr. ROLAND. I would preface my remarks by saying that I represent the University of Southern California, an academic institution. We do not do any technical research. We teach the principles of safety. We have been doing this for about 25 years, and we have had approximately 1,600 pilots come through the school to learn some of these principles. I am going to examine this problem of aviation safety from an academic or systems point of view.

Commercial aviation is a relatively safe mode of travel. It is safer by an order of magnitude than the private motor vehicle. Motor travel, is occasionally criticized for its safety but it generally accepted by the American family. This same family at times will hesitate to place all of its members together in a commercial aircraft for discretionary travel. Nevertheless, the safety record of commercial aviation as measured by objective standards is quite good. However, the public's perception of risk frequently does not hinge on objective standards. The major factor which influences the public perception of risk in commercial aviation is the spectacular nature of the accidents, where a large number of deaths are accompanied by heavy media attention.

I think we must first accept that there is no quick fix or easy improvement to the state of safety in commercial aviation. The quick and easy things were done in the 1950's and 1960's. The reduction in the various rates by which we measure aviation safety should continue at a slow but steady pace to improve if we properly apply our knowledge of the human in complex aviation systems.

Aviation safety is, of course, multidisciplinary, involving the triad of the human, the machine, and the environment. Each interacts with the other in complex ways. Altering factors in one influences the other two in sometimes ways which are not well understood. I cannot point to a single major technical deficiency or human shortcoming which, if corrected, would result in a dramatic improvement in commercial aviation safety. However, all of us testifying here today have indicated a number of areas in which improvements can be made. Taken together, these improvements will result in an enhanced state of safety.

At the outset, we should be aware that man is a causative element in the aircraft accident, be it design, production, or operation. This in itself is not a magic wand which we may wave to achieve our goals, but it will guide us in our deliberations.

Airports are essentially what they will be in the foreseeable future. In most cases, runways are of adequate length and well lighted. However, encroaching cities cause problems. In Los Angeles, for instance, the blackness of ocean arrival and departure may cause disorientation of the pilot. On the other hand, arrivals and departures over heavily populated lighted areas are regulated. Reduced power climbs and high angles of descent introduce a degree of hazard. Of course, such maneuvers may be made safely most of the time. Only a careful study of the risk imposed can determine if such regulations are acceptable over the long run.

Care is then required in negotiating agreements with the cities, which appear workable in the short run but suddenly increase hazards in takeoff and landing.

A major hazard for commercial air continues to be general aviation. The general aviation aircraft are small and difficult to detect by the control system. In addition, the pilots are less disciplined than commercial pilots, which causes difficulties when trying to maintain positive control. However, the gradual spread of radar transponders has alleviated some of this problem, and an increasing ability of the controller to detect altitude with transponders is of considerable assistance in maintaining traffic separation.

Of course, our present capability to place all aircraft in 22 congested terminal areas under positive control is a marked improvement. Our goal is to increase the number of these areas.

The principal tool of management in improving the degree of safety is regulation. However, the pilot who has the final responsibility for safety of the passengers and airframe, operates with a certain degree of independence. The positive degree of control which is possible in surface transportation is not present. Furthermore, the pilot has a greater number of degrees of freedom in the movement of his vehicle in space than does the surface operator. The pilot, by his very isolation, has a choice of which regulations to obey or the degree to which they are obeyed.

Beyond the formal regulations, the management system contains the unwritten rules of which the pilot is aware. The disruption of the schedule which will occur, if he goes to an alternate airport or removes the aircraft from the takeoff queue to return to the flight line for deicing, is always in his mind. Such formal and informal regulations must always be viable, and this viability well understood by the pilot. They must properly balance financial loss against safety. This means that the cost of disrupting the normal course of events must be properly balanced against the expected loss of an accident. Such a balance is always present, whether or not it is recognized. This must be true because the only completely safe flight operation is no operation at all.

The heart of safe operations in and around airports depend upon the pilot remaining alert to the dangers, responding with proper actions to perceived hazards, and obeying the regulations and corresponding standards or practices and doing these things consistently, day in and day out. To do so requires a knowledge of the "why" of the regulation or standard. It is understanding the "why" which causes the motor vehicle driver or the aircraft pilot to conform to the letter of the rule or take that extra precaution when the less knowledgeable may not. I would suggest that it is education which brings an understanding of this "why."

We are all aware that the aircraft may fail unexpectedly, and at times and mysteriously. When lives are lost, we demand that the unexpected be anticipated and corrected prior to its occurrence. Traditional machine safety has depended on the known precedent for hazard reduction. The fault occurs, it is investigated, and causes are discovered and corrected. In the case of the catastrophe, this may be unacceptable.

There arose with the design of our first solid state ICBM, substantial questions concerning the occurrence of events which were too disastrous to be allowed to occur even once. The possibility of inadvertent launch had to be considered and controlled to that which would be judged acceptable. From this situation there arose a set of analytical tools and management methods to discover and control hazards prior to their first occurrence. This body of knowledge is known as system safety.

Since its inception back in the early days of the Minuteman, it has evolved to a standard which is applied to all large Department of Defense systems which have a potential for great loss in a mishap. These techniques have now evolved to be applied to fully operational systems. These techniques were used to analyze chemical facilities, refineries, nuclear power plants and other large scale systems for major loss potential. These techniques have not been used on some of the commercial aircraft flying today.

There is an inside joke in safety about the response which is sometimes received when the safety of a new and expensive and complex system is questioned. That response is a rather indignant, "We design safe systems." What is meant by this response is: "This organization uses good design practices which have been commercially successful for years, and no reason is seen to alter them. Why ask us to change now?" Why indeed.

I would suggest that a system safety design standard be developed and implemented by FAA for the design of all commercial aircraft. Furthermore, I would suggest that system safety methods be applied to an analysis of commercial aircraft operating procedures.

I cannot close without a few words about the human, who is of course the most important element in the safety triad of the human, the machine and the environment.

The human designs, produces, operates, and manages the system. Of course, it is the loss of human life which is the most unacceptable of all the consequences of an accident. It is the human who is the most fallible. It is relatively easy to design a small, electromechanical component with a failure rate of 1 to 10 to the minus 4 per unit exposure. However, the human failure rates on simple tasks vary from 10 to the minus 1 to 10 to the minus 3, depending on the stress level under which the task is being performed.

Beyond the fallibility of the human, there exists problems of the psychological needs of the human managers and operators. Professor Chaytor Mason of my department at USC believes there is a wealth of information confirming that pilots fulfill their stereotyped characteristics by being active, masculine individuals. This translates into individuals who are strong, competent, adventuresome, enjoy their working life, mastering the forces of nature and the physical and technical field in which they must perform.

Two recent studies have shown that pilots differed markedly from the male population at large. These studies show that rating pilots on the Edwards Personal Preference Schedule, including navy pilots and general aviation pilots and also a general sample of males, on 16 personality characteristics, that the pilots ranked significantly higher in the areas of achievement, exhibition, dominance, change, and of course heterosexuality. They scored significantly lower, however, than the random group of males in the characteristics of deference, order, affiliation, succorance, abasement, and nurturance. There was little significant difference between the pilots of the military and nonmilitary group, indicating that these are characteristics of males who choose flying as a vocation.

This character profile indicates an individual who enjoys taking chances, mastering his environment, and is not easily influenced by the admonition "Be careful." This individual's chosen course of action is not easily altered, except through his personal understanding of the magnitude of the risk. For this individual it is not sufficient for others to promulgate standards which they must blindly follow, knowing that if followed an adequate margin of safety will result. It is essential that this individual understand the safe course of action, having either learned from personal experience or having been educated to an in-depth understanding of the rules and standards.

The job of flying commercial aircraft can at times be quite boring. Much of the time is spent in monitoring automatic systems. A life-threatening emergency may arise only a few times in a career. Conformance to rules and standards or procedures does not always provide a balance between a safe operation and an efficient operation. From some acquaintance with the average airline pilot's education and training conducted by the airlines, I believe it may be improved. It is recommended that commercial pilots' education be supplemented in both the human factors and the technology of the flight vehicle.

At the present time, the National Transportation Safety Board does not have a school for the formal training of new aircraft accident investigators. Investigators receive their training in accident investigation on the job, working with experienced investigators. At this time, they are working with formally trained investigators, however at some future informally trained investigators will be the instructors. There is a growing perception that the quality of the investigations has already degraded slightly. As time goes on, there is concern that this will continue with further quality decreases.

Accident prevention depends, in part, upon the quality of the investigation. There is a link between investigation and the resulting countermeasures and to the ultimate state of safety in the system. It is recommended that formal training for NTSB aircraft accident investigators be reestablished.

Finally, we must mention management. It is management that provides signals to the pilots as to what actions will be criticized or complimented. It is management that provides the resources to support measures for increased safety. Management must properly motivate and control the adventuresome, dominant, pilot personality. Management, of course, has the final say for the bottom line in the operation: profit. A low level of safety will eventually reduce profit. However, a short term approach to profit generation at the expense of safety may at times be tempting.

In summary, I would like to observe that no single area of commercial aviation safety is so deficient that a countermeasure imposed there would result in marked improvement in the safety performance of the overall system. There is, however, room for improvement, even after years of steadily increasing safety emphasis and reduced accident rates. This improvement will come from the selective application of countermeasures in each of these three areas of the safety triad, the human, the machine, and the environment.

Finally, I would like to observe again that few safety countermeasures will be effective without the full support of airline management. This is not to suggest that airline management may not believe in safety per se. Safety in commercial air transport is like motherhood: all concerned parties will support the concept. What management must fully support are the means of achieving safety and demonstrate this support with the resources and attention necessary to make these countermeasures work.

[The prepared statement of Dr. Roland follows:]

STATEMENT OF HAROLD E. ROLAND BEFORE THE INVESTIGATION AND OVERSIGHT SUBCOMMITTEE AND THE HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY

Commercial aviation is a relatively safe mode of travel. It is safer by an order of magnitude than private motor vehicle, a mode of travel which is occasionally criticized for its safety but is generally accepted by the American family. This same family at times will hesitate to place all of its members together in a commercial aircraft for discretionary travel.

Nevertheless the safety record of commercial aviation when measured by objective standards is quite good. The major airlines accident rate per 100,000 departures of .459, was in 1981, roughly one-half what it was in 1972. This despite a substantial rise from the 1980 rate of .274. The fatal accident rate was .076 per 100,000 in 1981, again substantially below the rate of 1972. However the public's perception of risk frequently does not hinge on objective standards. The major factor which influences the public perception of the risk in commercial aviation is the spectacular nature of the rare accidents in which a large number of deaths are accompanied by heavy media attention.

In spite of the foregoing, those of us close to commercial aviation are aware that the safety record can be improved--that the causes of accidents are vulnerable to countermeasures. Recent human failures invite our attention but do not show us the way to properly apply such countermeasures. We are concerned with disasters resulting from human mistakes or electro-mechanical failures. Our intuition tells us that improvement must be possible.

First we must accept that there is no quick fix or easy improvement to the state of safety in commercial aviation. The quick and easy things were done in the 1950s or early 1960s. The reductions in the various rates by which we measure aviation safety should continue at a slow but steady pace if we properly apply our knowledge of the human and the complex aviation systems.

Aviation safety is a multidisciplinary problem involving the triad of the human, the machine, and the environment. Each interacts with the other two in complex ways. Altering factors in one influences the interaction with the others, sometimes in ways which are not well understood. For instance, improving the capability of the aircraft to fly in adverse weather conditions may cause the pilot to press forward into conditions which are beyond his capability and perhaps beyond the enhanced capabilities of the aircraft. Because of such interactions I cannot point to a single major technical deficiency or human shortcoming which if corrected would result in a dramatic improvement in commercial aviation safety. However I believe I can indicate a number of areas in which improvements can be made. Taken together these improvements will result in an enhanced state of safety.

At the outset we should be aware that man is a causative element in all aircraft accidents, be it in design, production, or operation. This in itself is not a magic wand which we may wave to achieve our goals but it may guide us in our deliberations.

THE ENVIRONMENT

If we consider for a moment the operating environmental state of commercial aviation, it should be divided into two parts. The physical environment comprises the enroute and terminal control system, the nature of the atmosphere to include the weather, and the alloted airspace, and the surface facilities. The management system in which the pilot and machine must function is the other element of environment which influences safety. This includes the host of regulations, both formally promulgated and informal agreements or understandings which govern the manner in which the aircraft operates.

Our airports are essentially what they will be in the foreseeable future. In most cases the runways are of adequate length and well lighted. Where winds are a factor we usually find additional runways to alleviate unacceptable crosswinds. However the encroaching cities cause problems. In Los Angeles the blackness of ocean arrival and departure may cause disorientation for the pilot. On the other hand arrivals and departures over heavily populated and lighted areas are regulated. Reduced power climbs and high angles of descent introduce a degree of hazard. Of course such maneuvers may be made safely most of the time. Only careful study of the risk imposed can determine if such regulations are acceptable. We must recognize that for the nearby populace, airports provide no benefits to balance the noise and risk of a crash. These people are not deterred by their arrival after the establishment of the airport. They can exert political pressure which could compromise safety. They perceive no benefits from the airport and are thus unwilling to reach any agreement acknowledging its right to operate. Care is required in the negotiation of agreements which appear workable in the short run but subtly increase the hazard of takeoff and landing.

After years of joking about weather forecasting, some improvements are being effected. However changes in destination weather from poor but above minimums to "below minimums" is still difficult to predict. Coping with such situations depends upon the skill of the pilot and the technical capability of the aircraft.

The air traffic control system does not appear to be as bad as it seemed to be only a year ago. Operating under flow control (as presently exists until there are adequate numbers of personnel) it seems to be a satisfactory but not superior system. This means that some hazardous situations will occur which must be circumvented by the human and technical redundancies in the system. Improved radars and computers are desirable. A major hazard for commercial air continues to be general aviation. The general aviation aircraft are small and difficult to detect by the control system. In addition the pilots are less disciplined than commercial pilots which causes difficulties when trying to maintain positive control. However the gradual spread of radar transponders has alleviated some of this problem. An increasing ability of the controller to detect altitude (through transponders) is of considerable assistance in maintaining traffic separation. The capability to place all aircraft in congested terminal areas under positive control remains a goal which must be achieved if the hazard of mid-air collisions is to be reduced to an acceptable level. The major hazard facing commercial aviation is the midair collision. This hazard is vulnerable to appropriate countermeasures.

The management of the operating environment is essential to its safety. We are aware of what seems to be increased safety with the improved management of the Air Traffic Control system at the present time. I use the word management in its broadest sense to cover management of the aircraft as well as the people in the system. The principal tool of management is, in this case, regulation; however the pilot, who has the final responsibility for the safety of the passengers and airframe, operates with a certain degree of independence. The positive degree of control which is possible in surface transportation is not present. Furthermore the pilot has a greater number of degrees of freedom in the movement of his vehicle in space than does the surface operator. The pilot, by his very isolation, has a choice of which regulations to obey or the degree to which they are obeyed. Beyond the formal regulations the environmental management system contains the unwritten rules of which the pilot is aware. The disruption of schedule which will occur if he goes to an alternate airport or removes the aircraft from the takeoff queue and returns to the line for further deicing, is always in his mind. Such formal and informal regulations must always be viable and this viability well understood by the pilot. It must properly balance financial loss against safety. This means the cost of disrupting the normal course of events must be properly balanced against the expected loss of an accident. Such a balance is always present whether or not it is recognized. This must be true because the only completely safe flight operation is no operation. Thus the pilot and to a certain extent the controller must be aware of the balance between safety and operational efficiency as the aircraft is guided from point to point. A proper balance requires a thorough education and a skilled and dispassionate operator. More will be said of this when we discuss the human in the triad.

The heart of safe operations in and around airports depends upon the pilots remaining alert to the dangers, responding with proper actions to perceived hazards, and obeying regulations and corresponding standards and practices. Doing these things consistently, day and day out, when the degree of hazard may not always be as great, requires more than discipline. It requires a knowledge of the why of the regulation, standard, or practice. It is an understanding of the why which causes a motor vehicle driver or an aircraft pilot to conform to the letter of the rule or to take that extra precaution when the less knowledgeable may not. For instance an understanding of how easily the force of lift may be spoiled by a deviation in the curved surface over which air flows can cause a pilot to take the extra precaution against the icing hazard. The pilot who merely remembers the fact but does not understand why, may proceed assuming others will warn him if the condition is unacceptable.

It is education which brings an understanding of the why. The establishment of more detailed or more specific regulations is not an answer in itself. Regulations which are unnecessary or not well understood as to need, are violated. Regulations or procedures cannot be written to cover every eventuality. We must depend upon the understanding and judgment of the operating personnel. Safe operation in a confined environment depends upon enlightened regulations, accompanied by a thorough understanding of the forces of nature, and the dynamics of the flow of traffic.

THE MACHINE

We are all aware that the aircraft may fail unexpectedly and at times mysteriously. When lives are lost we demand that the unexpected be anticipated and corrected prior to its occurrence. Traditional machine safety has depended on the known precedent for hazard reduction. The fault occurs, it is investigated, the causes discovered and corrected. In the case of catastrophies this may be unacceptable.

There arose with the design of our first solid state ICBM, substantial questions concerning the occurrence of events which were too disasterous to be allowed to occur even once. These missiles sat in their silos with guidance gyros spinning, their propulsion systems at instant ready. The possibility of inadvertent launch had to be considered and controlled to that which would be judged acceptable. From this situation there arose a set of unique analytical tools and management methods to discover and control hazards to that which would be acceptable prior to the first accident. This body of knowledge is known as System Safety. Since its inception, back in the early days of Minute Man, it has evolved to a standard which is applied to all large Department of Defense systems which have the potential for great loss in a mishap. The techniques have now evolved to be applied to fully operational systems. These techniques are used to analyze chemical facilities, refineries, nuclear power plants and other large scale systems of major loss potential. These techniques have not been used on some of the commercial aircraft flying today.

There is an inside joke in safety about the response which is sometimes received when the safety of a new, expensive, and complex system is questioned. That response is a rather indignant "We design safe systems". What is meant by this response is that this organization uses good design practices which have been commercially successful for years and no reason is seen to alter them. Why ask us to change now? Why indeed.

I would suggest that a System Safety design standard be developed and implemented by FAA for the design of all commercial aircraft. Furthermore I would suggest that System Safety methods be applied to an analysis of commercial aircraft operational procedures.

THE HUMAN

The human is, of course, the most important element in the safety triad of human, machine, environment. The human designs produces, operates, and manages the system. And it is the loss of human life which is the most unacceptable of the consequences of an accident. The human provides the degree of redundancy which allows the use of systems which would have a loss rate far too high to be operationally feasible without that human back up. The X-15 program is the classic example of a system which could not have been operationally feasible without the human as an integral element of the control system.

Strangely enough it is the human that is most fallible. It is relatively easy to design a small electro-mechanical component with a failure rate of 1 x 10^{-4} per unit exposure. However the human failure rates on simple tasks vary from 1 x 10^{-1} to 1 x 10^{-3} depending upon the stress level under which the task is being performed.

Beyond the fallibility of the human there exists problems with the psychological needs of the human managers and operators. Professor Chaytor Mason of my department at the University of Southern California believes there is a wealth of information confirming that pilots fulfill their stereotype characteristics of being active, masculine individuals. This translates into individuals who are strong, competent, adventuresome, enjoy their working life, mastering the forces of nature and physical-technical field in which they must perform.

Two recent studies have shown that pilots differ markedly from the male population at large. These studies at two Michigan universities using the Edwards Personal Preference Schedule, graded Navy pilots, general aviation pilots, and a general sample of males on 16 personality characteristics. This study found that pilots ranked significantly higher in the areas of achievement, exhibition, dominance, change, and heterosexuality. They scored significantly lower than the random group of males in the characteristics of deference, order, affiliation, succorance, abasement, and nurturance. There was little significant difference between the pilots in the military and non-military group indicating that these characteristics are those of males who choose flying as a vocation.

This character profile indicates an individual who enjoys taking chances, mastering his environment, and is not easily influenced by admonitions to "be careful". This individuals chosen course of action is not easily altered except through his personal understanding of the magnitude of the risk. For this individual it is not sufficient for others to promulgate standards which they must blindly follow knowing that if followed an adequate margin of safety will result. Management's rules are also difficult for this individual to follow, particularly when they are tempered with such bottom line considerations as operating efficiency and profit. It is essential that this individual understand the safe course of action having either learned from personal experience or having been educated to an in-depth understanding of the rules and standards. Such in-depth knowledge also facilitates safe flight for this strongly macho personality, in situations where there are no rules or standards.

The job of flying commercial aircraft can be, at times, quite boring. Much of the time is spent in monitoring automatic systems. Where driving a bus requires continuous control inputs from one destination to the next, pilots of a commercial aircraft find themselves monitoring instruments and waiting for the next position report. The life threatening emergency may arise only a few times in a career. The pilots must respond quickly to these situations balancing the requirements for continued normal flight operations against the risk involved. Conformance to rules or standards or procedures does not always provide such a balance. In such situations only a thorough understanding of the underlying relationships may suffice.

From some acquaintance with the average airline pilot's education and training conducted by the airlines, it may be improved. It is recommended that the commercial pilot's education be supplemented in both human factors and technology of the flight vehicle.

At the present time the National Transportation Safety Board (NTSB) does not have a school to formally train their new aircraft accident investigators. Investigators receive their training in accident investigation on-the-job, working with experienced investigators. At this time they are working with investigators who have formal training in investigation. However at some future time informally trained investigators will be be the instructors. There is a growing perception that the quality of the investigations has already degraded slightly. As time goes on there is concern that this will continue with further quality decreases. Accident prevention depends, in part, upon the quality of accident investigations. There is a link between accident investigation and the resultant countermeasures, to the ultimate state of safety of the system. It is recommended that formal training for NTSB aircraft accident investigators be reestabished.

The final area of man's involvement in the safe operation of the commercial aircraft is through management. Management establishes the framework of rules and practices within which the operational areas of the airline function. It is management that provides the signals to the pilots as to what actions will be criticized or complimented. It is management which provides the resources in support of education for increased safety. Management must properly motivate and control the adventuresome, dominate, pilot personality. Management has the final responsibility for the bottom line in the operation, profit. A low level of safety will eventually reduce profit. However a short term approach to profit generation at the expense of safety may, at times, be tempting. Increased education of pilots involves cost as does operational conservatism. I believe that enlightened management believing in safety to the extent that they back that position with resources, will produce an improved state of safety.

In summary I would like to observe that no single area of commercial aviation safety is so deficient that a countermeasure imposed there would result in a marked improvement in the safety performance of the system. There is however, room for improvement even after years of steadily increasing safety emphasis and reduced accident rates. This improvement will come from selective application of countermeasures in each of the three areas of the safety triad, the human, the machine, and the environment. Finally I would like to observe that no safety countermeasure will be effective without the full support of airline management. This is not suggest that airline management may not believe in safety per se. Safety in commercial air transport is like motherhood. All concerned parties will support the concept. What management must fully support are the means of achieving safety. They demonstrate this support with the resources and attention necessary to make the countermeasures work. Safety must start with management and proceed down through the system.

Thank you for your attention and consideration.

Mr. GLICKMAN. Thank you very much, Dr. Roland.

Dr. Miller?

STATEMENT OF DR. C. O. MILLER, SYSTEM SAFETY, INC., McLEAN, VA.

Dr. MILLER. Thank you, Mr. Chairman. I noticed in the agenda that I was identified as having been with the National Transportation Safety Board. I trust the committee will appreciate that I have spent equivalent time as an operational pilot, including being a test pilot and engineer in the aerospace industry. I also have taught at the USC Safety Institute. And since being at the board last in 1974, I have been involved in a lot of things, not the least of which is aviation law.

I think this background is important because I would like to think my prejudices are balanced out to some degree. As a matter of fact, I showed my paper to a friend the other day and he said, 'You have been thinking about this." I said, 'Yes." And he said, 'You know what thinking is? It is simply a realinement of prejudices." So I suppose that is why I am here.

Mr. GLICKMAN. We in Congress appreciate that kind of testimony.

Dr. MILLER. You will note from my printed text that I have covered some of the so-called technical areas which your letter of invitation indicated, but I also chose to go off in a slightly different direction. As a matter of fact, I am not sure if our presence here in the Judiciary Committee room is not somewhat appropriate, as perhaps will become obvious later on.

But let me first touch quickly on these so-called technical areas that have been the subject of most of your testimony, not only this year, I am sure, but perhaps in many other years.

I do believe, for example, that the principal basic and applied research areas should be in the matter of crash fire protection. However, in the matter of cabin fire safety or aircraft interior combustion, which I agree is important, I am not convinced that we do not know all we really need to know on that subject for a while. I think the emphasis here should be on implementing the existing technology, not trying to repeat what NASA's people did on the space program many years ago.

Similar to that, I think we as a Nation have gone far enough for now in researching crashworthiness, meaning the structural integrity during impact, and indeed crash impact dynamics, unless the emphasis is given to proof-of-principle testing in a prototype.

I walked in here this morning during the presentation by the FAA. I can only say that Dr. Hugh DeHaven must have turned over in his grave. If you are not aware of Dr. DeHaven, he was the gentleman in the thirties and the forties who first identified the principles of crash injury prevention. I personally in 1962 did a survey of the available literature which dealt with the knowledge in terms of human tolerance and things of that type.

For me to hear a major U.S. official today say that we have to learn more about human tolerance to deceleration using restraint systems can be described in polite terms only as incredible. I could think of some other terms, but I do not believe your record would appreciate them. The FAA is not only wrong, but they have been for 20 years in this aspect of their business. I am appalled at what I heard this morning, and I will take on anyone who cares to debate the issue further at any time.

In the matter of icing, the current investigation of the Air Florida flight 90 accident has highlighted at least a couple of voids in our knowledge, as I think you may have realized. First there is a question of how a flight crew can be expected to know when an ice or snow condition has reached a critical level during protracted ground operations prior to start of takeoff roll, or in flight for that matter.

The suggestions heard at the public hearing this past week were either rather crude, like "How you find this out is by running your hand across the top of the wing," or bureaucratic when the FAA keeps coming back and saying, "The pilot shall not begin the takeoff roll with snow or ice on the aircraft."

I am sorry Mr. Dunn is not here. He had an interesting suggestion—stationing an observer at the active runway—and I wanted to tell him why I do not think it would work: it does not cost enough. Yet I do not think his suggestion is mutually exclusive from the attitude taken by Captain O'Donnell. I would hate to think that a pilot, at any time, has to depend solely on his own judgment. I see the suggestion of Mr. Dunn being not unlike the man who used to stand at the end of the runway and tell me, by one method or the other, "Get your wheels down." I can talk more about this 737 accident later, if you like.

The fifth item I mentioned, in my prepared text is the overall generic area of weather-induced or environmental inputs to the safety equation. I will let you read the sea story in my paper. I will go on to say simply that I think in practical terms, you must identify these things adequately to the pilot, and then turn things over to him.

There is a hardware area that has not been mentioned very often. As a matter of fact, I was pleased to hear it mentioned at this hearing this morning. I am talking now about cockpit voice recorders and flight data recorders. I have personally been involved in recommending this through the contacts throughout the country for the better part of 5 to 7 years.

Another area that I was again glad to hear brought forth has to do with the relatively new family of hazards that, as my friend Professor Edwards in London says, "transcends liveware and software, as well as hardware." The "liveware" are the people, of course. We are into a whole new area, in my opinion, on these computer-based system problems. Fortunately, both the President's Task Force on Crew Complement and the National Academy of Science's study, which is just about to be released—both of which I was a part of—have tried to identify this. I would strongly counsel the committee to pay attention to both of these reports in this particular area.

But now to get to an item I am not sure you have ever heard before. I am talking about research projects which have not traditionally fallen within the area of science and technology but which, in my opinion, have every bit if not more of an impact in getting things done about accident prevention than a lot of things that we hear about. I am not trying to degrade these traditional tasks, but you cannot stop there.

The theme of Dr. Roland's presentation was unknown to me when I prepared my statement. However, I, too, wrote in terms of safety management or system safety, these being terms of art which both of us have grown up with. Some people have called them institutional factors. Using any term, we see problems in the integration of skills, resources, and knowledge to prevent accidents. These problems can be traced to policies, resources, laws, public moods, and so forth, which make the decision and implementation process regarding remedial action complex indeed.

I see no reason, however, that these problems, these roadblocks which are preventing the prevention of accidents, cannot be effectively attacked by professional and indeed scientific inquiry. In my paper I list what is probably just a few of these problems. The first is an absence of a Federal safety policy. I am not sure how many people will appreciate my comment when I say, "Do you settle for a highest degree of safety or highest practical degree of safety?" The FAA Act, for example, is not clear on this point. Yet, I can assure you, decisionmakers will take either side of that question, depending on what point they are trying to argue.

I mentioned, secondly, the deleterious effects of litigation on the exchange of safety information. I have sat in trials in which the manufacturer's representative admits that they have destroyed all evidence pertaining to certain kinds of accidents in their files going back earlier than 2 years ago. Now, how in heaven's name can their follow-on designers be expected to know the bitter lessons of the past if the data have been destroyed?

Third, I list the confused role of the so-called independent regulatory oversight agencies like the NTSB, with close corollary there, too, being the question of the qualifications of the members of such groups and the agency's relation to line organizations such as the FAA.

Fourth, I cite the absence of a truly integrated national safety information exchange system, involving all segments of aviation. We learn something in air carrier, but we do not get it to general aviation, or vice versa.

Fifth, there seems to be a lack of hazard analysis methodology that transcends mere hardware or other limited subsystems of the overall aviation system. As recently as yesterday, I came across a proposed FAA design analysis report which, if you were to look at it, you would think they never heard of the term "human factors." Again, fortunately, our National Academy of Sciences study, which I am not at liberty to discuss at length, tries to get at this, but what we are seeing in both NASA and the FAA are people confusing the term "reliability" with "safety" or the understanding or correlation thereof. I can assure you that they are different, and the difference to a great extent is the input of the human operator.

We do not have comprehensive accident models. For example, when those of us who are experienced think of a midair collision or icing, our computer on the end of our neck sits there and says, "You had better look at certain things." Unfortunately, we have not organized that protocol yet, at least in a manner that could make the data collection meaningful and indeed make the research more effective.

Finally, and this is perhaps implied in the other areas I have mentioned, there is a gross failure in many, if not most, of the decisionmakers to understand human error. They tend to seek blame and, once found, stop thinking altogether let alone rearranging their prejudices.

In summary, I have tried to be responsive to the subjects mentioned in the committee's letter of invitation, but I have also attempted to introduce a new dimension to safety research that may well get beyond the obligations of this committee. It is the safety management or system safety area, which in my view requires problem resolution at least as critically as the so-called technical questions.

[The prepared statement of Dr. Miller follows:]

AVIATION SAFETY RESEARCH AND RELATED ISSUES

by

C. O. Miller

System Safety Inc.
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Presented at a Hearing of the House Science and Technology Subcommittees on Transportation, Aviation and Materials, and Investigations and Oversight, Washington, D.C., March 9, 1982.

AVIATION SAFETY RESEARCH AND RELATED ISSUES

The invitation to present these comments is appreciated sincerely. November 1982 marks my 40th anniversary in aviation... a career which as included activity as a pilot, aeronautical engineer, human factors specialist, accident investigator, educator, program manager and non-practising lawyer. I have worked extensively in the military, aerospace industry, university, Federal Government and private consultant environments. I have planned, pursued and performed aviation safety research. I have my biases. I only hope they are received as being based upon experience, not conjecture.

My most recent exposure to the research world came last year in connection with two projects. I was a participant on the President's Task Force on Aircraft Crew Complement, and a member of the National Academy of Sciences (National Research Council) Committee on Cockpit Crew - System Interaction. The former hopefully resolved the two versus three-man cockpit argument. The latter study, requested by NASA to assist them in structuring their aviation human factors research, has essentially been completed. The review of the report is in progress, and whereas I am constrained from discussing it until its release, my comments here have been influenced by my association on the Academy committee.

I shall begin with the premise that "government aviation and aircraft safety research", as phrased in the Committees' invitation to appear, may be interpreted broadly to include both basic and applied research. Indeed, as will become more apparent shortly, I shall take an even broader view of needed safety research than perhaps the Committee has been exposed to heretofore. This is necessary because, in my view, the fundamental difficulty today regarding aviation and more precisely, aviation safety research, is the presence of roadblocks to application of research results to real-world problems. That, in itself requires study or "research", if you will.

Expressed somewhat differently, "science" and "technology", when related to "aircraft safety research", traditionally have been concerned with the material things...usually hardware ...and usually engineering solutions thereto. By way of example, look at the list of programs outlined in the invitations to appear: "crashworthiness, crash impact dynamics, runway traction, cabin fire safety..." et al. The scientist or engineer researcher responding to such a shopping list has visions of some new knowledge breakthrough or some new manufacturing process leading to some new gadget that will prevent accidents or injuries. Of course, that is fine; indeed, great. Technological improvements can and should be made in most of those areas. I shall discuss some of them in a moment.

But let us not forget, for example, that irrefutable evidence was available to show the lifesaving benefit and practicality of shoulder harnesses in military aircraft during World War II and in civil aircraft by no later than the mid 1950's, yet the FAA never required shoulder harnesses in general aviation aircraft until 1977. Knowledge gained through technical research per se will not prevent accidents.

However, as to the conventional areas of possible safety research noted in the Committees' letter of invitation, I summarize my views as follows:

1. The primary basic and applied research tasks should rest in the area of crash fire prevention. This should include not only the fuel flammability aspects but also containment through detail design characteristics of the fuel systems including their components and location within the airframe.

2. Cabin fire safety/aircraft interior combustion is important; however, I submit the solutions are already here. Thus, more research in the classic sense could be suspended or at least slowed down. The emphasis should be on implementing existing technology.

3. Similar to the above, I believe we, as a nation, have gone far enough for now in researching crashworthiness (meaning structural integrity during impact) and crash impact dynamics unless the emphasis is given to proof of principal testing in prototype configurations for given type aircraft, e.g. general aviation. Aviation could take a lesson from the automotive folks who demonstrated the practicality of various crash injury prevention designs through full scale and quite practical vehicles.

4. In the matter of icing, the current investigation of the Air Florida Flight 90 accident has already highlighted a couple voids in our knowledge that bear research consideration. First is the question of how a flight crew can be expected to know when the ice/snow condition has reached a critical level during protracted ground operations prior to start of takeoff roll, (or in flight, for that matter). The suggestions heard at the public hearing last week were either rather crude ("run your hand across the wing") or bureaucratic ("the pilot shall not begin the takeoff roll with snow or ice on the aircraft"). Second is a full explanation of why pitchup and/or roll will occur with given wing configurations such as the B 737 when it has not been reported operationally with other aircraft.

5. Other weather phenomena effects continue to provide surprises including turbulence in all its forms, effects on runway traction, wind shear, extremely heavy rain

> particularly when accompanied by a "downburst", etc. I am not convinced, however, that we need to know more about the phenomena except as necessary to allow us to indentify it in practical terms so that flight crews can avoid the hazard. This would include such seemingly mundane things as better understanding of the perception, decision and response process generic to the low experience general aviation pilot who gets into weather over his head, literally as well as figuratively.

Considering the "surprise" of weather or environmental phenomena in a broader context, I'm reminded of a young Marine 2d Lieut. near the end of World War II when he was checking out in the "Corsair". The posters, the brochures and the instructor said, "Take 'er up, son, she's yours...now you can fly over all the clouds". So I arrived at 35,000 feet sucking oxygen and wondered what all that billowing white stuff was above me!

That same story has been repeated in principle at various later points in my career. Wake turbulence was not supposed to do-in large aircraft until a DC-9 did an incomplete slow-roll at fifty feet during an approach to land at Amon Carter airport in Fort Worth behind a DC-10. Wind shear also was supposed to be only a small airplane problem until Eastern Flight 66 disrupted ground traffic at JFK airport in New York by leaving bits and pieces of wreckage and bodies lying about just short of the runway. Water density in rain was never supposed to be more than a nuisance until it made a glider out of a DC-9 at New Hope, Georgia a few years ago. Watch the "tube" daily for the latest returns from the icing knowledge front. As implied from (4) above, we seem to have a long ways to go.

One "hardware" area not mentioned very often but which I believe would be highly beneficial to air safety would be the development of lighter weight, low cost and improved fidelity cockpit sound recorders and flight data recorders. Note I said cockpitsound recorders as distinguished from simply cockpit voice recorders. The total sounds attendant to an accident are significant, not just verbal communications. These and perhaps other accident investigation tools are needed if we are ever to get back to effective accident investigations within reasonably allocated resources, particularly in general aviation.

Another area that has posed a relatively new family of hazards transcends the hardware, software, liveware (people) triad. That area is the computer based systems introduced en masse in the new generation of jet transports, but also found to a significant degree in corporate and other forms of general aviation. I refer to such systems as RNAV (area navigation), INS (inertial navigation systems), heads-up displays, flight management systems (optimized aircraft performance through computer aided mission and systems analysis) and automatic takeoff, landing or go-around systems. Both the President's Task Force on Crew Complement and the National Academy of Sciences studies mentioned earlier expressed interest and/or considerable concern that the interface between the pilot operator and the rest of these systems is not well understood. Thus safety research in this area merits high priority.

Finally to come to the matter which I suspect may not been brought to the Committee before: consider those research projects which traditionally have not fallen within "science" or "technology" but which can have every bit if not more impact on accident prevention than the more "technical" items discussed above. I choose to classify them under the general heading of "safety management" or "system safety", the latter being a term of art meaning essentially the same thing as safety management to many people. Some might think of them as "institutional" problems.

Using any term, we see problems in the integration of skills, resources and knowledge to prevent accidents. These problems can be traced to policies, resources, laws, public moods et al which make the decision and implementation process regarding remedial actions complex indeed. I see no reason, however, that these problems...these roadblocks which are preventing the prevention of accidents...cannot be effectively attacked by professional, indeed, scientific inquiry. I list what is probably just a sampling of these problems as follows:

1. The absence of a Federal safety policy...the need for something that distinguishes as a national posture, for example, whether we shall pursue or settle only for the "highest degree of safety" or will we accept the "highest practical degree of safety", meaning accident prevention consistent with a viable air transportation system. (For further discussion on this subject, see Miller, C. O., "Comparative Analysis of Federal Legislative Mandates for Public Safety", Proceedings of the System Safety Society Fifth International Conference, Denver, CO, July 29, 1981.)

2. The deleterious effects of litigation on the exchange of safety information...a very controversial subject with constitutional law overtones. Safety ramifications of past proposals for a Uniform Products Liability Act would be another way of describing this issue.

3. The confused role of the National Transportation Safety Board (NTSB) as a so-called independent regulatory or oversight agency...with close corollaries thereto being the question of qualifications of Board Members and the agency's relation to the aviation line organization, the FAA.

4. The absence of a truly integrated, national safety information exchange system involving all segments of aviation...with the objective being to preclude the continuous re-learning of the bitter lessons of the past - with continuous tragic results.

5. The lack of hazard analysis methodology that transcends mere hardware or other limited sub-systems of the overall aviation system...the need to recognize the total scope of accident causation, and effectively design-out the hazards or better assign procedural controls before the system becomes operational.

6. The lack of comprehensive accident "models"...analytical or investigative tools which can greatly lend meaning to the collection of accident/incident information and, above all, place substance to the use of such data.

7. The failure of many, if not most, decision makers to understand human error...meaning the propensity to seek blame and once found, stop the thinking process.

The need exists to examine and resolve these problems in a system safety context, with the "system" not necessarily being confined to aviation. Perhaps if we could get on with projects such as resolving the above issues, aviation might once again be looked upon a leader in technology developmenmt in the publidc interest.

In summary, I have attempted to be responsive to the subjects mentioned in the Committees' letter of invitation to attend the hearing. I have also attempted to introduce a new dimension to "safety research"...the safety management or system safety area...which, in my view requires problem resolution at least as critically as the so-called "technical" questions.

Many of us professionals in the field, of course, feel we already have answers to at least some of the questions posited. However, let's face it, identifiaction of principles and problem solutions through a hypothesis and testing/measurement approach (i.e. "research") was necessary to Newton even though he knew all along the apple fell downward! If we have to "research" something to get others to believe (as well as learn answers to previously unsolved questions), sobeit.

Mr. GLICKMAN. I want to thank you both for excellent testimony, some of the best that we have heard, and I would like to ask a couple of questions.

Dr. Miller, I understand that you have been attending the NTSB hearing concerning the Air Florida crash. I wonder if there is any way in a brief period of time that you could summarize what you have heard so far, particularly as it might relate to the issue of aviation safety research.

Dr. MILLER. Certainly, sir. I was there until 10:15 this morning. This whole question of icing has raised its ugly head. I do not think there is any secret, and I think the facts are irrefutable that icing at least was involved in the diminished power for takeoff. I think that the degree to which wing ice was involved was not fully discussed, although there was some testimony there.

I know of no one who does not agree that confusion reigns concerning the deicing procedures. Like you and others at this hearing have commented today, it is again nothing short of incredible.

I would counsel the committee to get, as soon as possible, the transcript of two witnesses' testimony from the NTSB. One is a Mr. Adams from the FAA's Aeronautical Research Center, which took place yesterday afternoon, and one earlier from a Mr. Trump, who is the manufacturer of deicing trucks. If you would like to see a microcosm of what is wrong with aviation safety research, I suggest you to read those two areas of sworn testimony. It is a conflict between the real world and the bureaucracy. I think I could be here all afternoon going further, but I will let it go at that.

I would make only one other comment. I have a very strong suspicion, based on what I heard particularly this morning but not limited thereto, that what we are looking at would be generically classified as a deregulation accident. I think we are seeing things, for example, the failure of the transfer of information, which arose as a result of what I call the deregulation effort.

Mr. GLICKMAN. Let me follow up on that question, because Captain O'Donnell referred to that. You are saying that because of the economics of flying commercial aircraft today, issues involving operation and maintenance are being shortchanged?

Dr. MILLER. I am not suggesting or implying that they are being shortchanged deliberately. I think it may be a natural fallout of the extremely competitive nature and the setting up of relatively new organizations that do not have the benefit of 10, 20, or 30 years of experience. When you look at some of the testimony as I have heard it—and I would prefer not to go further than that at this time—I think there is a strong suspicion of the impact of deregulation causing this accident.

Mr. GLICKMAN. I think that is an area that is obviously of great significance for us as legislators to deal with. It is also particularly relevant, because several of the largest commercial carriers are about ready to become insolvent. It is of great concern for the flying public too. There is not much more we can do to explore it today, but I think it is important that the issue is raised.

I would like to discuss one more issue with you, and that concerns the NTSB. Do you think the NTSB is doing a good job, particularly as it relates to identifying needed safety research?

There is a second part to that question. As you are aware, and both of you gentlemen may wish to comment, there is no requirement that NTSB members have any experience in any transportation area whatsoever. There is legislation floating around here to mandate that, but I thought you might both want to comment on that.

Dr. **Miller**. First of all, I think the investigation of Air Florida 90 demonstrates what the NTSB can do given proper leadership, motivation, and resources, and quite frankly, I do not think they have had in recent years any one of the three. I think there have been some very severe investigation shortcomings of the NTSB and FAA work in recent years, particularly in general aviation. I think Flight 90 shows what can be done under the right circumstances.

I do believe, however, and perhaps more to the point of your question, that NTSB recommendations have been in my judgment, consistently good. A lot of people take them as gospel. They are never put out to be gospel. They are put out only within the framework of the capabilities and background of the people there. They do make people sit back and wonder, and to me that is the first step of research, and therefore it is helpful.

On your second point about qualifications, I have very recently sent a letter to the Senate Commerce Committee who, I guess along with Mr. Mineta in the House here, has introduced a bill requiring certain qualifications for all five board members. I never thought it would come to that. But quite frankly, because of my experience in recent years, I have supported the bill, and I would limit my other comments to what is in that letter. I have made a copy of this available to one of the staff.

[The information follows:]

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February 25, 1982

Senate Commerce Committee
Room 5202,
Dirksen Senate Office Bldg.
Washington, D.C. 20510

Dear Sirs and Mesdames:

The purpose of this letter is to comment on S 1936, the Bill to require specified qualifications for prospective members of the National Transportation Safety Board. My position is basically one of support; however, for reasons noted below, I believe any Committee discussion on the Bill may also wish to consider some other factors in its attempt to rectify the highly unsatisfactory situation that has developed at the Board in recent years.

My perspective for offering these comments is, I believe, unique. As observable from the enclosed personal background summary, I am extremely well qualified in the areas noted in the Bill, "accident reconstruction, safety engineering, human factors, transportation safety, or transportation regulation".

More importantly, I have been what might be termed an "NTSB Watcher" since the time I served as Director, Bureau of Aviation Safety of the Board from 1968 to 1974. I have studied, written and spoken extensively on the Board's activities in recent years. I have made my detailed views known to your Committee staff members and others such as House Committee and GAO personnel.

Indeed, my testimony before your Committee and in the investigations preceding the Independent Safety Board Act of 1974 led somewhat to the Act's development and passage. Thus I am no stranger to the NTSB or its functions.

As stated above, I generally favor S 1936 although in the past, I had not felt, nor did I want to believe, that it was essential to go as far as requiring all Board members have the specified qualifications. I learned while at NTSB and subsequently the value of relatively lay opinion as a necessary input to Board deliberations. It is very easy to get caught up in the action of the current catastrophe and with continuing exposure to such events, lose perspective of the general public.

As presently written, however, the law allows grossly unqualified personnel to be appointed to the Board...and such appointments have been made by both Parties. Especially as it applies to the appointment of Chairperson, it can be and has proven to be disasterous. At the very least, some persons who have been appointed to the Board have spent a couple years or more just trying to learn the language. They are at the mercy of staff personnel, many of whom are now really not capable in their own right; particularly those who found there way into key positions, not because of their capability but rather as the spoils of a political campaign. Many Members and staffers alike are at the mercy of their own conscience. They generally try to do a good job; it's just that they really have not been prepared for it.

Some of the past Board members have seen NTSB as simply a stepping stone to more lucrative positions in politics or business. Their interest in the true purpose of NTSB was transitory at best. Other Board members whose qualifications on paper were totally unimpressive, were very hard-working, dedicated public servants.

With the above thoughts and my previous communications with Committee staff members as background, please accept the following suggestions as supplements to my general support of S 1936:

1. To counter the expected and reasonably valid point that will be made by opponents of the Bill about need for lay person input to the Board, consider the formation of an advisory committee under the law. Such an advisory committee could then also include representatives of various activities such as NASA, the Military, State Government groups or others whose interface with NTSB needs to be improved, thereby enhancing NTSB's effectiveness. It is not deemed important for lay person decision-making. Lay input and that of certain other groups is deemed necessary in an advisory sense.

2. Clarification of the role of the Chairperson is needed in relation to the authorities of the other Members. It is suggested that he or she be clearly given policy and procedure determination authority within the law, with the other Members given authority only in adjudictory matters (major case cause determination and certificate actions), or when the Chairperson chooses to delegate tasks acceptable to the other Members.

3. The Chairperson should not only meet the criteria stated in the Bill but also be of such national prominence publically and "technically", that he or she will present an encouraging image to the public not unlike that of high ranking Justices of our leading courts.

4. Professional safety groups such as the American Society of

Safety Engineers, the System Safety Society, the International Society of Air Safety Investigators et al should be canvassed for proposed nominees to the Board in a manner not unlike the guidance sought from the American Bar Association for nominees to the bench.

5. Appreciate that the so-called "technical" qualifications of Board members, especially the Chairperson, must include demonstrated management capability and sensitivity to the Washington process. Without this, all the other experience might never have a chance to surface.

In conclusion, and my prior critical comments about the Safety Board here and elsewhere notwithstanding, they serve an important role in all our lives. They have tried in recent months to improve things. They need the help in the form of Bill S 1936 and other considerations too detailed to describe here. Without such help, there will be needless and costly loss of life and degraded effectiveness of our transportation system in the future.

Should the Committee choose to have a hearing on this Bill, I would welcome the opportunity to appear to testify. Alternatively, I would be pleased to amplify remarks during a personal visit to your office upon request.

Respectfully,

COMiller

C. O. Miller

Mr. GLICKMAN. Thank you.

Dr. Roland, do you have any comments?

Dr. ROLAND. As far as I am concerned, in this area I did make a comment about the investigators in my testimony, the fact that they are not formally trained and I think they should be. Investigation today, as the aircraft become more sophisticated, with computer systems in them, and with some of the natural phenomena that create things like ice where we did not anticipate ice, I think we need people with a little more formal investigation training than the new investigators have.

As for the board, I think the board needs at least a core of technical competence in the field. Whether every member must conform to some standard, I do not think that is necessary, but I think they need a core of technical competence at that level.

Dr. MILLER. Mr. Chairman, may I add one point, please? I had occasion to give a talk on December 9 to an accident investigation meeting sponsored by the Air Line Pilots Association, attended by people from all over the aviation community. It was on this subject of the adequacy of the NTSB investigations. Again, I would suggest that your committee ask ALPA for the transcript of that proceeding which is being prepared.

I might also say that in my remarks there, after commenting critically, I said:

There are only two things I think could turn this around. One, there might be an investigation by the GAO or some committee of the Congress; or two, there is going to have to be a catastrophic accident, preferably near Washington, D.C.

Mr. GLICKMAN. You were unnecessarily prophetic.

Dr. MILLER. I am afraid so, sir.

Mr. GLICKMAN. Mr. Gore?

Mr. GORE. Do both of you think that Mr. Dunn had basically a sound recommendation or suggestion?

Dr. ROLAND. In what regard?

Mr. GORE. To have an individual at the end of the runway spotting for ice?

Dr. ROLAND. As far as I am concerned, that is the kind of thing that is simple, practical, and might work very well. Of course, the military has been using it for years in regard to wheels, to see that landing gear is down. You can have all kinds of sophisticated systems and warning lights and so forth, but a man out there on the end of the runway waving to you, giving you a signal that your wheels are down, is the final positive step that will assure you do not land unless they are. I think, with regard to ice, this may be a very practical way of approaching it.

Mr. GORE. Dr. Miller?

Dr. MILLER. This is what I started to say earlier. I know J. J.'s feeling about pilot responsibility. We get into the same argument when we talk about air traffic controllers providing information on very turbulent weather. I think you can retain the pilot's authority and responsibility, if you will, and still provide him with this other information which is, after all, a backup system.

We design aircraft time and time again with backup hardware systems. All we are doing here is designing with a backup human system.

But do not underestimate the difficulty of even somebody outside being able to tell whether that airplane is improperly iced. The reason I say that is, one of the issues in this Air Florida 90 case is how well the 737 wing performs with very subtle ice on either the leading or trailing edge high-lift devices. That has not been resolved yet, and I think one of the things that came out in the NTSB hearing and is indeed in some of the publications, is that you can get certain ice conditions that cannot be seen visually.

This is why one of my suggestions was in this area that somebody ought to come up with a probe or device that can identify the presence of ice rather than depending on the eyeball, although we will have to go with that for now and be conservative.

Mr. GORE. As an interim step, it makes sense to have a spotter?

Dr. MILLER. I certainly would not argue against it.

Dr. ROLAND. It certainly does.

Mr. GORE. We often overestimate the preference for these high-technology solutions to problems. If you can have a spotter catch 70 to 80 percent of the problems, maybe that makes sense.

What is the optimum mix, Dr. Miller, of glycol and water?

Dr. MILLER. I do not think it is known. If you go on the basis of the people who testified at the hearing, who seemed to have the most operational experience—and I think that is all you have to go on right now—I think you are talking about first getting rid of the ice to begin with, deicing it with steam or hot water. Then depending on the particular environmental conditions, again a judgment call, you can go as high as 65 percent glycol. But I do not believe there is anything definitive, in a research sense, that is going to answer that question. It was posed by several of the people at the NTSB hearing, and nobody in that room seemed to have any answer to it.

Mr. **Gore**. You talked about the deleterious effects of litigation on the exhange of safety information. How can we solve that problem?

Mr. **Miller**. Well, there was, among other things, a model uniform products liability bill that came through and was not acted upon for one reason or another. I believe that somewhere in such a law, there is going to have to be a qualified privilege established for certain kinds of information exchanged between people working in air safety. It has been a long-discussed item. Even before I went to law school, which was relatively recently, I was pushing this. I have seen enough in the basic law to convince me that qualified privileges can be assigned and can be held to a test of constitutional law. Frankly, I am not quite sure I see the difference between lifesaving efforts of a physician as opposed to an air safety investigator.

Mr. **Gore**. I am most impressed with the testimony of both of you. Was it you, Dr. Roland, who suggested that the NTSB investigators have scientific training, that you reestablish that requirement?

Dr. **Roland**. They do not have any formal training now.

Mr. **Gore**. But they used to?

Dr. **Roland**. They used to have a school, about a 1½ to 2 years ago.

Mr. **Gore**. Why was that requirement removed?

Dr. **Roland**. I presume it was a funding problem.

Mr. **Gore**. A funding problem?

Dr. **Miller**. I am certain it was a funding problem.

Mr. **Gore**. Now the investigators do not have to have any training?

Dr. **Miller**. Just on the job, and I presume they hire people who——

Mr. **Gore**. Pick it up as they go along?

Dr. **Miller**. I wish you were right. I do not believe that is true. They have people who have never investigated an accident, out on the scene for the first time in the company of another investigator.

Mr. **Gore**. That is ridiculous, it seems.

Dr. **Roland**. Yes, it seems that way to me also. Our contacts with investigators in aviation around the country have found that it has now reached a point where you can note that the investigation quality has degraded.

Mr. **Gore**. How long was that former requirement in effect?

Dr. **Roland**. How long did they have the school?

Mr. **Gore**. Yes.

Dr. **Roland**. A long time.

Dr. **Miller**. A long time before I went to the board in 1968, I know that.

Mr. **Gore**. It was just done away with a year or a year and a half ago?

Dr. **Roland**. Late 1979 or early 1980, I believe.

Mr. **Gore**. I think that the report that comes out of this hearing is going to have a large number of constructive suggestions. I think that these two subcommittees are going to remain very active in this area, following through on these recommendations. You two, in particular, have made a number of excellent suggestions, and I appreciate it.

Thank you, Mr. Chairman.

Mr. **Glickman**. Mr. Walker?

Mr. **Walker**. Thank you, Mr. Chairman.

Drawing on both of your long experience in the matter of safety in the industry, does either of you know of anybody who agrees with the FAA in their position with regard to structural safety of seating in aircraft, the testimony that they gave earlier here today? Does either of you know anybody who agrees with the contentions made here?

Dr. **Miller**. Among the people who I consider to be knowledgeable in the crash survivability field, I know of no one outside the FAA who has taken this position. Again, I would suggest that your committee, if you have not already done so, contact one Dr. Jerry Snyder at the University of Michigan on this particular subject. I think he is the most well-informed person in the world on this subject.

Mr. **Walker**. Dr. Roland?

Dr. **Roland**. It was my understanding that the FAA took a hard look at rearward facing seats when the military decided to convert some years ago. They found, talking to the airlines, that the airlines had determined that people did not like to fly that way, as we have heard testimony today, and sort of forgot about it.

Mr. **Walker**. In other words, what you are saying is that the airlines would say that people do not like to fly backwards on it, but you do not know of anybody who has research that would back up what the FAA is saying today?

Dr. **Roland**. No, I could not lay my hands on a document on this, but I remember reading things to this effect.

Mr. **Walker**. Are we then saying that consumer preference has played the biggest role in a safety decision here?

Dr. **Miller**. Yes, sir, in the backward seating, I would say that without question. Again, I know of no technological argument that suggests that it is not safer, with a properly designed seat, to face backwards in an air carrier crash.

Mr. **Walker**. Really what we are dealing with is perceived consumer preference, isn't it, because I do not think that consumers have ever been told that the facing backwards might be a safety factor for them.

Dr. **Miller**. I believe there were actually some studies made in that area 10 or 15 years ago or more. The thoroughness of them and certainly their applicability in 1982 is another question.

Mr. **Walker**. I guess this has nothing to do with the real issue, but having flown aboard some of those military planes and flown backwards, once you are in the air you do not know the difference. It is not something that is a bothersome kind of thing once you are actually flying. When you are on the ground, you notice a little bit of difference, but in the air there is relatively little difference.

Most consumers would not object to it after a period of time, particularly if it were safer.

Dr. Roland, your testimony indicates that many of the quick technical fixes in air safety have already been made. Would you identify for the committee those areas in which improved technology can still make a substantial contribution?

Dr. **Roland**. I am not sure about the outstanding contribution, but I think there are a number of small areas. We have just been discussing one—and I do not know if you would call this pure technology: rearward facing seats—but that is going to reduce injuries, without any question, if they would go to that.

I think that there could be some improvement in the reliability of the aircraft system by the imposition of a system safety standard in the design process of new aircraft. We are not quite as far out as we might be there, because it turns out that the Boeing Co. is a leader in system safety, and they have done a lot of the system safety work on their own initiative in the design of their new product. However, I know that some of the other companies are not quite so active, and I think that some of these problems could have been anticipated with a good system safety design standard. Now, this is kind of an across-the-board approach to technical correction of little problems on aircraft.

Mr. **Walker**. Let me put it this way. It is really a question for both of you. If each of you had to identify a single major area that should receive the highest FAA priority in terms of developing technology that would substantially increase air safety, which area would you likely pick?

Dr. **Roland**. I would pick midair collision. I think they should work hardest on that.

Mr. **Walker**. Mr. Miller?

Dr. **Miller**. If I may go across-the-board on the total spectrum of aviation, I would suggest better understanding of how you can analyze the system design and minimize the effects of human error therein.

Mr. **Walker**. Thank you, Mr. Chairman.

Mr. **Glickman**. I thank both of you for excellent testimony. It was very productive testimony.

[Material follows:]

PAST RECOMMENDATIONS TO THE NTSB AND OTHERS FOR IMPROVED AVIATION ACCIDENT INVESTIGATIONS

by

C. O. Miller

System Safety Inc.
McLean, Virginia

Presented at the Air Line Pilots Association seminar, "A Review of Recent Aircraft Accident Investigations by The National Transportation Safety Board", Dec. 9, 1981, Washington, D.C.

FOREWORD

These pages have been prepared to supplement the undersigned's appearance at a panel discussion December 9, 1981 sponsored by the Air Line Pilots Association. This panel is to be part of a two day meeting with the theme, "A Review of Recent Aircraft Accident Investigations by the National Transportation Safety Board"(NTSB). The panel's specific topic is "Procedural and Legislative Alternatives."

Attached first is a numbered list of personal papers and/or speeches presented in recent years in which recommendations have been directed principally to the NTSB in the interest of improving aviation accident investigations. Comments are included as to what manner the thoughts were made available to the Board.

Next is a tabulation of the specific recommendations quoted from their original presentation. Many were repeated subsequently in one form or another; hence all sources of the recommendations have been denoted by the numbers shown in parentheses corresponding to the list of presentations. The tabulation is chronological and emphasizes not only NTSB procedures and practices but also human factors investigations.

Included as the last eight items, numbered (28) through (35), are requests made by formal petition to the Safety Board on March 25, 1981. The Board summarily dismissed the petition without even holding a meeting on the subject.

What little action is known to have been taken by the Board on the other items is also shown by notes on page 8; however, this is not to imply such action was necessarily in direct response to these recommendations.

Finally, the last pages present an outline of remarks expected to be made preceding the panel question and answer session. This includes decision options which seem to be facing the government powers that be and the aviation community.

COMiller
C. O. Miller
Dec. 5, 1981

PRESENTATIONS BY C. O. MILLER CONTAINING RECOMMENDATIONS CONCERNING AVIATION ACCIDENT INVESTIGATIONS

1. "Legal and Litigation Barriers to the Communication of Human Factors Safety Information", presented at the Flight Safety Foundation International Seminar, Williamsburg, VA, Nov. 12, 1974.
   (Forwarded to the Board Chairman by correspondence)

2. "The Public's Total Stake in Aviation Accident Investigation", presented at the 7th International Seminar sponsored by the International Society of Air Safety Investigators (ISASI), Arlington, VA, Sept. 28, 1976.
   (Meeting attended by numerous NTSB personnel and paper was forwarded to the Board Chairman by correspondence.)

3. "Human Factors Accident Investigation and the Question of Pilot Decision- Making", presented at the ALPA Symposium on Human Factors, Wash., D.C., Feb. 8, 1977.
   (NTSB personnel in attendance at the meeting.)

4. "Behind the Facts", presented at the 23rd Annual Flight Safety Foundation Corporate Aviation Seminar, Arlington, VA, Apr. 10, 1978.
   (NTSB personnel in attendance at the meeting.)

5. "U. S. Civil Aviation Accident Investigation and the Law", Potomac School of Law, Aug., 1979. Edited and published as "Aircraft Accident Investigations: Functional and Legal Perspectives" by the SMU _Journal of Air Law and Commerce_, Vol. 46-2, Winter, 1981.
   (Both versions forwarded to the Chairman of the NTSB and each other Member by individual correspondence.)

6. "Human Factors in Accident Investigations", presented at the Dutch Airline Pilots' Symposium on Human Factors in Civil Aviation, The Hague, The Netherlands, Sept. 6, 1979. Published in _Legal Eagles News_, Nov. 1979 and the _ISASI Forum_, Spring 1980.
   (The articles were presumably read by at least some of the NTSB staff.)

7. "Coordination Between Parties in Civil Aircraft Accident Investigations: the Pathway to Improved Social Justice and Accident Prevention", presented at the SMU Air Law Symposium, Dallas, TX, Apr. 3, 1981.
   (Forwarded to the Chairman, NTSB and each Board Member by individual correspondence.)

PAST RECOMMENDATIONS

1. Government and industry should institute a specific **training program for aviation managers** and other senior aviation officials so they understand the fundamental meaning of **human performance**, particularly as it relates to error avoidance and motivation for safety. (1), (2), (6)

2. Government or industry develop and disseminate a practical **protocol for the investigation of the human factors** aspects of accidents, particularly in the area of psycho-physiological variables germane to personnel performance. (1), (2), (6), (7)

3. Government civil aviation authorities and aviation operations managers should issue **policy statements**, making it clear that hazard identification through **incident-reporting** is required in the best interests of safety to the public and except in those few instances of the most severe, gross negligence, no adverse action would be taken involving the individual reporting the information. (1), (6)

4. The airlines of the world and other operators of aircraft which have **cockpit voice recorders** aboard should declare formally that the CVR records will **never be used as the basis for disciplinary action** against the flight crews. (1), (6)

5. **Probable cause** determination should be **either eliminated** as a statutory requirement by Federal governments **or so defined** as to preclude its being interpreted as a single causation factor or one that can be construed as fault in the legal sense. (1), (5), (6), (7)

6. **Research** should be undertaken jointly by representatives of the legal and safety professions to identify means of securing more comprehensive **accident/incident information of a personal performance nature** without unnecessarily jeopardizing the rights of the individuals concerned. (1), (6)

7. The Administration and the Congress remaining or coming into power in 1977 do something to implement the provisions of the Independent Safety Board Act dealing with **safety professional competency on the Board.** (2)

8. As at least an interim step to the above, the Safety Board should use consultants and/or form an intermodal **safety advisory group** composed of top safety experts in given modes to advise the Safety Board as to the adequacy of its products as seen from the "outside" and on such other matters as it deems

important. (2), (5), (7)

9. The Safety Board should implement the long planned **selectivity program** for aviation accident investigations which better channels available resources to specific kinds of cases. Similarly, it should obtain statutory relief if necessary to stop required cause determination in those cases in which a reasonable investigation cannot be done for financial reasons. Some consideration should be given to eliminate "probable cause" as the legally defined end point in any of the cases. (2), (5), (7)

10. The Safety Board should **cancel (old) Part 831.6 (a)** of its regulations that precludes parties to field investigations and the hearing if they represent claimants or insurers, and **substitute a requirement that all parties**, or at least their principal spokesman, **be qualified** and certified through a process that ensures their contribution in accident prevention efforts as well as fulfillment of their other obligations. (2), (5)

11. In support of the recommendation immediately above, the International Society of Air Safety Investigators should develop a **training curriculum** and otherwise propose a professional **certification program** that it might administer on behalf of NTSB and other countries' investigative bodies. (2), (5)

Note: For items (10) and (11) here, also see (28) - (33) below.

12. The Safety Board and the FAA should initiate a crash program to **upgrade** their **investigations from a human factors point of view.** (2)

13. The **aviation community,** (airlines, trade associations, manufacturers, etc.) should prepare for even **more extensive participation in accident investigations** than in the past, if comprehensive, accurate findings are desired. (2)

14. **Cockpit voice recorder fidelity and timing accuracy** when referenced to the flight data recorder and air traffic control tapes should be improved since the CVR is probably the best, if not the only, investigative tool available to the human performance investigator. Consideration should be given to **renaming it a Cockpit Sound Recorder (CSR)** since intelligence derived therefrom goes well beyond voices per se. (3), (6)

15. **CSR's** should be installed **in general aviation aircraft** - selectively - at government expense, if necessary, to provide better human performance information during mishap investigations. (3), (6)

16. Far more **use of simulators** should be made early in the

investigative process. This should be a first order consideration any time crew performance appears to be at issue. The fact determination process should not be considered complete without this step. (3), (6)

17. The accident **data coding** used by NTSB and ICAO should be reexamined and modified to **reflect more human factors/performance information and eliminate the blame connotations** of many of the existing descriptors. (3), (4), (6)

18. More in-depth **investigation of training details** as they affected the accident and coding thereof should be accomplished. (3), (6)

19. NTSB should issue a **policy statement concerning** past and existing **use of "probable cause"** referring to both narrative and computerizd formats. (4)

20. NTSB should propose **legislation that eliminates** the statutory requirement for **"probable cause"** and leaves the degree and method of cause assessment and recording a matter of Board purview. (4),(5), (7)

21. NTSB should **convert to an "all cause" concept** as soon as the statutes permit it. (Reference the USAF and other Military Services approaches) (4), (5), (7)

22. NTSB should include summaries in their reports of significant views by qualified parties which are contrary to the **opinions of the NTSB** staff or findings by the Board. Use of technical review conferences subsequent to the field fact finding phase is encouraged in this regard. (5)

23. NTSB should delineate policies and procedures to define minimum acceptable **standards for all investigations**, especially in the human factors area. (5)

24. **NTSB** should modify its **organization** to encompass an aviation program manager concept to encourage adequate emphasis is given to aviation matters. The senior official for aviation should be at a grade level equivalent to the intermodal functional chiefs. (5), (7)

25. The American Bar Association (particularly the Aviation Law Committee) should develop a process whereby **litigation-derived findings** concerning aviation accidents can be **fed back to NTSB** accident records, even if it is no more than a citation reference system. (5), (7)

26. A committee of the International Society of Air Safety Innvestigators comprised of both air safety specialists and attorney members, (or, alternatively, a joint venture with the

Aviation Coimmittee of the American Bar Association) should develop a **policy statement regarding privilege** and the acquisition and dissemination of information for accident prevention purposes as compared to litigation purposes. This should include issues raised by foreign accidents. (5), (7)

27. **Government and industry leaders** who can make and implement decisions regarding aviation accident investigations (should) please **read and try to understand the recommendations** that have been made to improve human error accident investigations (and) **act on them** to prevent accidents. (6)

28. That **Parts 831 and 845 of the Board's rules be modified** to include a requirement that **investigators representing all parties** to the investigation or hearing **be certified** by the NTSB per standards developed with the assistance of an NTSB Advisory Committee and/or the International Society of Air Safety Investigators; such requirements to include, as a minimum, specialized training in the technical field for which the investigator is being proffered and specific indoctrination in NTSB policies and procedures. (7)

29. That all **FAA personnel** who conduct accident investigations on behalf of the NTSB be subject to **qualification** and certification requirements analogous to those noted above for non-governmental parties. (7)

30. That **Parts 831.9(c) and 845.13(b) be deleted**, thereby **removing the restriction against** representation in field investigations or hearings by "**any person who also represents claimants or insurers.**" (7)

31. That the NTSB ensure **reasonable notification of appropriate parties** who may wish to participate in the field phase of the investigation through qualified representatives as described above; such parties to include, among others, families of passengers, crewmembers or persons on the ground killed or seriously injured. (7)

32. That NTSB **expand the "observer" status** to include representatives of deceased or seriously injured passengers, crewmembers or persons on the ground, if such (parties) choose not to provide qualified investigators. (7)

33. **Alternatively to (31) and (32)**, that the NTSB appoint a qualified person to function as an **ombudsman** or public counsel capacity to preserve the rights of the injured or their families during the investigation.

34. That the NTSB adopt a modification to the technical review conference concept to require that a specific **debriefing of all parties be provided prior to completion of the field phase** of each accident to elicit ideas for further safety

investigation and/or preservation of evidence for examination and use later. This should be accomplished before drafting of reports by the investigator or hearing officer. (7)

35. That the NTSB promptly issue in the Federal Register a **notice of proposed rule making** reflecting rule and procedural changes implicit from the above (items 28 - 34, **and** conduct an appropriate **public hearing** related thereto. (7)

Note:

Of all of the above recommendations, only three are known to have been accomplished to one degree or another since they were offered.

- KLM Royal Dutch Airlines has instituted a human factors training program for flight crews and others. Ref. Item (1).
- Members of the NTSB staff presented papers recently at an ISASI seminar outlining a human factors investigation protocol. However, it has not yet been implemented significantly, nor will it be, given current fiscal constraints. Ref. Item (2)
- NTSB has revised its coding of reports including human factors notations. The results are expected to become public early next year. Ref. Item (17).

PROCEDURAL AND LEGISLATIVE ALTERNATIVES

I. How Did Today's Situation Come to Pass

A. Steady erosion of resources allocated to the aviation accident investigation function by:

1. NTSB internal practices (for over a decade).
2. Congress/OMB (since the Safety Board Act of '74).
3. Economic conditions of recent years

B. Degradation of the aviation function by NTSB leadership by:

1. Elimination of a separate investigation quality control function within the Board.

2. "Demodalizing" the staff which included marked downgrading of the senior aviation-only officials.

3. Placing the "technical" chiefs in line reporting positions relative to politically appointed, usually unqualified, administrative personnel.

4. Emphasis on form rather than substance of accident investigations in the name of "productivity".

5. Failing to enforce its own rules to ensure objectivity during accident investigations.

6. The limiting of training and liaison of the staff with the aviation community.

7. Failing to accept/promote the "all cause" concept.

8. Obvious unwillingness of the Board Members, singly or jointly, to acknowledge publicly that accident investigation problems exist; nor have they been willing to listen to, let alone reasonably consider, advice or criticism from any source.

C. Degradation of the aviation function by others by:

1. The Administrations (both Carter and Reagan) being willing to close their eyes to the intent, if not the letter of the law in terms of qualifications for Board Member appointees.

2. Ditto for the Congress.

3. The apparent willingness of industry (both operators

and manufacturers) to accept the diminishing of the Safety Board's competence since that would presume to make industry's oftentimes self-serving positions in the wake of accidents more appealing to their legal counsel and stockholders.

4. The working level staff at the Board if, and only if, they have not made it known to their supervision the degradation of professionalism they have been experiencing and have worked to do the best job they could under the circumstances. (Most undoubtedly have.)

II. Major Problem Areas Addressed by Past Recommendations

A. Human factors/performance investigation inadequacies.

1. Investigation protocol.
2. Training in human factors.
3. CVR/FDR inadequacies.
4. Legal and hazard-to-reputation inhibitors to free exchange of information.

B. NTSB policies and procedures

1. Antiquated "probable cause" philosophy.
2. Unrealistic party participation.
3. Degradation of aviation. (Reference above.)
4. "Head in the Sand" syndrome.
5. Unqualified people calling the shots.

C. Attitudes and practices not limited to NTSB leadership.

1. Lack of understanding of modern human factors technology.
2. Complacency about aviation safety ... acceptance of the status quo.

III. Solutions - Past and Present

A. Personal attempts to resolve problems described above by:

1. Leaving the Board in 1974 in protest to the change of job authority of the Bureau Director's position.

2. Writing and speaking on the problems noted above, being certain to include specific, and hopefully, practical suggestions.

3. Personal discussions with Board Members, industry representatives and Congressional staff members.

4. Coordination of the Mar. 25, 1981 petition.

B. General conclusion: Nothing significant will occur under the existing Board leadership or that as currently proposed unless some forcing function arises from:

1. Some major air disaster ... preferably near Wash., D.C.

2. An objective inquiry by GAO, one or more of the committees of the Congress, or a Presidential Task Force.

C. Assuming B-2 immediately above is the preferable solution, the reviewing group should:

1. Examine particularly those problems identified with NTSB policies and procedures (III B above)

2. Examine closely the possible abolition of the NTSB and assigning investigative functions to individual modes of transportation PROVIDED:

   a. A singular head of such an activity could be chosen with tenure and qualifications analogous to those of the non-political head of the GAO.

   b. He would report directly to the modal administrator

   c. He would be the final authority vis-a-vis the modal administrator of what information is released and when it is released to the public regarding accidents and related recommendations.

   d. A Safety Advisory Committee be an integral part of the mode's non-regulatory accident investigation/ accident prevention activity, (which should be combined) comprised of both lay personnel and safety specialists from various parts of the aviation community.

e. The Administration and/or the Congress develop a Federal Safety Policy as an umbrella of guidelines which would allow implementation of modern safety principles (e.g. the "all cause" concept) by safety professionals in any department, mode or office.

D. Concluding thought: Individuals or organizations perceived as having vested interests in suggested changes in the current ways of doing business are not going to be listened to, no matter how correct they may be. The question thus becomes how to influence non-participants in the accident process of the importance of resolving the severe air safety investigation problems and inequities that exist today.

Mr. **Glickman**. Our next witness is a panel of airport operators, Edward Wronkoski, manager of the Chemung County Airport, Elmira, N.Y., and Bob Michael, director of aviation at Stapleton International Airport, Denver, Colo., where I have been countless numbers of times.

Mr. Wronkoski, Congressman Lundine had stopped in before and had wanted to be here, but apparently there were conflicting hearings.

Mr. **Wronkoski**. I flew down with Congressman Lundine this morning. We had a discussion about this.

Mr. **Glickman**. We appreciate your being here, and you may feel free to summarize your statement in any way you wish, because your statements will appear in the record in their entirety.

STATEMENT OF EDWARD W. WRONKOSKI, MANAGER, CHEMUNG COUNTY AIRPORT, ELMIRA, N.Y.

Mr. **Wronkoski**. Mr. Chairman and members of the committee, first of all I would like to thank you for getting down to the bottom of the chain, and that is the small airport operator. We are a nonhub airport that serves a certificated air carrier along with a couple of commuters. We make up better than 60 percent of the airports of this country, and we are proud of the fact that we do not have too many accidents of major consequences.

I think it is going to happen one of these days, though, because small airports today, especially one my size, suffer from a lack of funds entirely. In Chemung County, we have 100,000 people. Our airport serves approximately 250,000 people. From our county, maybe 1 out of 20 will fly out of our airport once a year, and they do not want to contribute their tax dollars to the operation of that airport for other people's use. So as a result, we have minimal equipment, minimal maintenance. We try to do the best we can with what we have.

I think one of the greatest things that happened to the small airports was the forming of the Aviation Snow Symposium, the international snow symposium which was founded 16 years ago by a handful of airport operators and manufacturers who felt that the best way to make our airports safer, especially in wintertime, was to get together, exchange ideas, consolidate our thinking, and come up with better methods of keeping runways, taxiways, and aprons clear of snow, ice and slush.

Over the 16-year period, we have grown. Last year's attendance was over 300 attendees from the United States and 10 foreign countries. Along with airport operators, we have the manufacturers' representatives, we have airline pilots—United is very active, U.S. Air is active, and Piedmont is active. We have members of ALPA. We have members of NBAA. They all attend.

The main theme of the snow symposium is to let the man in the airplane know what is going on. Let us not surprise that guy in the airplane who is coming in for a landing. Do not let him have any surprises. Tell him exactly the conditions that he can expect when he is touching down.

I am going to tie a lot of this in together. The MU meter and the SAAB friction tester are probably great pieces of equipment. I doubt if we will ever know; we cannot afford them. Not only can we not afford them, we do not have the qualified people to maintain them, operate them, interpret them, or calibrate them.

We do not have these types of people. I have 12 men working at my airport, which encompasses over 1,000 acres of land. These men are in the salary range of $6 per hour, which is semiskilled labor. A lot of them probably have never been in an airplane. How do you train a person of that nature and instruct them so that the man in that airplane, flying 90,000 pounds of metal up there and maybe 100 passengers—because the largest that serves our airport is a 110-passenger DC–9; a lot of people—how do you train him to make him understand that the safety of 110 people's lives is at stake.

We do the best we can, and the snow symposium really gets this across. I take two of my maintenance people to Allentown every year to have them sit in there and hear these other ideas. Fortunately, I feel we do a great job. I am always running out of sand, and I am running out of urea, and I cannot afford it. Even if I could afford it, I cannot find it in the wintertime. This year I have gone through over 100 tons of sand. I do not have a place to keep it stored dry and heated, and it is a fighting proposition all winter long for the small airport operator.

The best thing that happened to the small airport, other than the snow symposium, was ADAP. It came along in 1970, and we really saw the light at the end of the tunnel. A lot of us went out and grabbed it; I was one of them. I built two new runways. I had three 4,000-foot runways deteriorated so bad that in some areas the water was a foot deep, and I have scheduled carriers coming in and out of there. Today, I have a 5,200-foot runway and a 7,000-foot runway, grooved.

And I would like to say something about grooving. I think it is the best thing and one of the safest things that could have happened to most of our airports. With grooving, solar energy plays a big part, because these grooves seem to absorb the sun's rays and melt the ice a lot faster.

We have new crash fire rescue equipment. I have strictly a volunteer fire department, well trained. I have a lot of navigational aids, ILS's and I'm getting more. I have good approaches, good overruns. I think we have a really safe airport. But I hear more and more rumbling from the small airport operator. Just recently, I have heard two of them say that their communities want to give up their airport because they just cannot afford to keep it any more.

I would like to go back to ADAP, which was probably the outstanding program. The user was paying for safety at his airport that he was going to be using. I am not sure I fully understand everything that has happened to that program, but around 1980 it just seemed to collapse. Over $4 billion sitting idle that these people put in for safety that they're being cheated out of. They are not getting a penny of it. Today, they reduced the user tax to 5 percent, and that 5 percent is not going into airports; it is going into general revenue.

I do not like to keep complaining, because after listening to all these people today, it seemed that a lot of what I heard was buck passing, trying to put the blame on somebody else. Maybe that is what we are trying to do.

We operate on a limited budget. We have very limited income. Your larger airports are usually self-sustaining. They have high financial profits in fact. Most of them turn in a profit to their community. A good example is, at my airport I get 22 cents per 1,000 for landing weight fees. I know at most of our larger airport in the New York metropolitan area probably get $1 or better per 1,000, and they have maybe 1,000 airplanes more than I have every day. So they are getting a lot of money in, and they can afford to do a lot of this, but we cannot do it without ADAP funds.

With regard to the indoctrination of our people, I am constantly taking my people out there to try to keep up with the changes. We do six field checks a day. I have them going out there. They do it in a vehicle. They come in and they can tell me or they can tell the aircraft operator—U.S. Air, in our case—exactly what the runway conditions are. They can tell them if it is icy or slippery, if the braking action is fair, poor, or nil. MU meter or SAAB friction measurement, fine: they confirm what we already know. We know it, and that tells us really how bad it is.

In some situations like Captain O'Donnell was talking about, I do not know. I have been a pilot for 25 years. I have not flown in several years now, but I have never seen two pilots that are alike. I watched a pilot on a commuter airlines one day on a 7,000-foot runway. At 4,000 feet down runway, he was still in the air. He touched down and went off the end and wrote it up as poor braking action. I agree with him: it's damned poor when you get down to that point.

But all in all, you are going to have accidents because you are going to have the human error and human factor. I was really impressed with Mr. Miller's talk. I thought he brought out some excellent points. We are going to have accidents. What we are trying to do is keep them down to the minimum and as minor as we possibly can.

I urge some of you gentlemen, who will be voting on this ADAP bill when it comes up, let us get it back in the ballpark where it belongs. I believe that is about all I have to say at this time. Let us not stop research; we need it, and it is important. But we also need to have the method and the means of carrying out the research that is found. They can tell us all they want about how good this is and how good that is, but if we do not have the funds to buy it or operate it or maintain it, they may as well leave it in the garage. Thank you.

Mr. GLICKMAN. Thank you for that excellent and pragmatic statement.

Mr. Michael, from Denver. It is a pleasure to have you here.

STATEMENT OF BOB MICHAEL, DIRECTOR OF AVIATION, STAPLETON INTERNATIONAL AIRPORT, DENVER, COLO.

Mr. MICHAEL. Thank you, Mr. Chairman. I have a lot of sympathy with Mr. Wronkoski. I used to be the manager of a small airport up in Montana and had the same kinds of problems that he has, in respect to limited staff and limited resources. That was even before urea, so the costs just go up even more so today.

I am not sure it is altogether as bleak as Mr. Wronkoski has painted for medium or larger airports. As he correctly pointed out, the larger the airport, the greater the opportunity for volume to create revenues. When you have a greater revenue stream, of course, you can do more with people and products.

You have a statement prepared by me. I do not intend to read it. I simply would like to cover a couple of the high points that may be germane to your thinking and your process today.

Under a 1972 regulation issued by the FAA, airport operators at commercial airports do have certain maintenance obligations with respect to how runway are maintained. Obviously the community felt it needed a runway to serve its people to begin with. But once it has accepted any kind of State or Federal funding, it has to maintain that, particularly if it has accepted Federal funding, in a condition which meets the criteria set forth in its operating certificate, again another device set up by the FAA.

Under that maintenance obligation, there are a number of things the airport operator has to do. Specifically with respect to the interests of these two committees, I think we are talking about keeping the runway clear of what the FAA generically calls contaminants. That could be snow or ice, on the one hand, in the wintertime obviously, or it could be rubber at any other time. Both of them have had a certain amount of investigation over time, depending upon what seems to be crucial at any given moment.

The airport operator is obliged to go out there and remove that snow or close the runway or the airport, but it is not quite that crystal clear. We obviously cannot do it immediately with the waving of a magic wand, nor can we keep it that way at all times during snowstorms. So there will be snow, there will be slush, and there will be ice to some degree that has to be reported. Now that is my point number two.

As Mr. Wronkoski mentioned, it really is a critical aspect of the airport operator to report the conditions, to report them accurately, and to report them on a timely basis. I think there have been instances where a runway condition has deteriorated somewhat from the last report, where the report made some time back may not be entirely representative of conditions that pertain at any given moment.

But having said that, I might also say that runway conditions can change almost immediately. There are plenty of places in the United States where the temperature and climate conditions are such that a light freezing drizzle, right around 32 degrees, can all of a sudden turn the airport runway literally into a sheet of glass. That happens almost as quickly as you can snap your fingers. Obviously, the airport operator has to take some action, and in that case probably simply drastic action: Either close the whole airport or restrict the movement of all vehicles or aircraft at the time.

Removal of contaminants, reporting, and then means of removing contaminants is where I would like to focus at the moment. There have been a number of techniques available to airport operators with increasing degrees of sophistication over the years. None of them are perfect. They all have time limits and ranges within which they work. Urea seems to work reasonably well. It is a broad-based nitrogen compound.

Mr. **Glickman**. What is urea?

Mr. **Michael**. It is a nitrogen compound that lowers the freezing point of water.

Mr. **Glickman**. We thought it might be some Federal agency.

Mr. **Michael**. Its effectiveness is somewhat limited with temperature, and also with the rate of snowfall. You can only keep up with it to a certain degree, but it is an effective agent. It is expensive, and it is not always available, and it has to be put down just right with some degree of anticipation, but it does work quite well.

One of the points that I choose to bring out in my written statement to you is, there is a clear line of demarcation with respect to responsibility as to whether an aircraft takes off on a runway that is something short of in perfect condition. As I mentioned before, the airport operator has the responsibility to remove any foreign contaminants. He also has the responsibility of reporting the condition. What he does not have the responsibility for is telling the aircraft operator whether he can use that runway.

Under FAR's, Federal Aviation Regulations, there are varying criteria under which aircraft operate at airports. We all know that when the ceiling is zero, visibility is zero, nobody is going to move. Technically, one type of aircraft operator can, but they generally will not. A commercial aircraft will not takeoff, nor will it land. If there is snow on the runway, there might be a couple of inches that has not been yet cleared. The chances are an air carrier's operating manual will not allow it to use it. The private aircraft might choose to use it, particularly if the wind happened to be right down that runway, and the one that everyone else is using is a crosswind.

The airport operator, from that perspective, is somewhat reluctant to close runways unnecessarily because they might be used by another segment of the system.

Beyond that, of course, if you get into emergency conditions, like a strong blizzard or a sheet of glass, where it really is dangerous for anybody to operate, the airport operator is likely to close not only the surface but the airport as a whole.

In summary, as I say in the very back of my statement, aside from providing a well designed and safe operational surface in the first place, the airport operator has the obligation to maintain these surfaces in a safe and usable condition. The Federal grant-in-aid process stipulates continuous maintenance as a condition of the grant receipt, and FAR part 139 provides definitive guidelines to insure that this condition is met. Airport operators have the never-ending obligation to observe and report accurately and timely the condition of all otherwise open and usable runways, particularly during periods of inclement weather. They also have the obligation to clear the runway of contamination as quickly as possible. Short of an overall emergency condition resulting in a closure, however, they do not have the obligation of determining what operator could use such a runway or the conditions under which it may be used.

That is the end of my statement.

[The prepared statement of Mr. Michael follows:]

AIRPORT OPERATORS COUNCIL INTERNATIONAL

Testimony

of

ROBERT S. MICHAEL

Director of Aviation - Denver-Stapleton International Airport

on behalf of the

AIRPORT OPERATORS COUNCIL INTERNATIONAL

on

AIRPORT AND AVIATION SAFETY

Before the Subcommittees on
Transportation, Aviation and Materials
and Investigations and Oversight

Committee on Science and Technology

U.S. House of Representatives

Washington, D.C.
March 9, 1982

International Headquarters: 1700 K Street, Northwest, Washington, D.C. 20006 **Phone:** (202) 296-3270 **Cable:** AOCIHQ

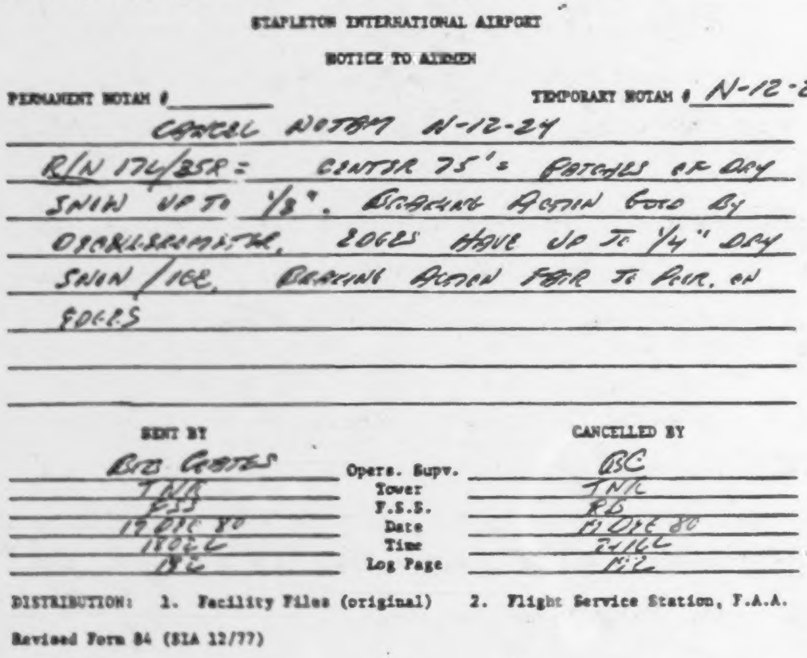
Gentlemen:

I am pleased to have the opportunity today to review briefly the role of the airport owner and operator as it regards the safety of runways at commercial airports in the U. S. It is my understanding that you are looking at this subject from the point of view of research and development and, more specifically, at runway friction measurements and the role of contaminants, particularly during inclement weather.

To review and examine the airport operator's role today, it is helpful to understand how we have evolved to our current posture. Initially, of course, the local community decided to construct one or more runways at its airport to provide its citizens the opportunity to enter the national transportation system. Assuming the airport was part of the National Airport System Plan (NASP), the community was eligible for and may well have received financial assistance under one or more of the now-defunct federal grant-in-aid programs. It may also have received some state financial help. If so, minimum design criteria established by the Federal Aviation Administration (FAA), and/or the state, based on anticipated type of aircraft usage and stage length, had to be met in order to qualify for the grant program. Further, the grant probably carried a condition (one of many) that the airport owners will maintain the runway and keep it serviceable for public use for some minimum period--usually 20 years.

Over the years, the methods used by the airport operator with respect to discharging this maintenance obligation evolved from a rather hit and miss proposition to one that is both regulated and effective. In 1972, the FAA adopted FAR Part 139 which requires airport operators to apply for, receive, and keep current an Airport Operating Certificate issued by the FAA. To be eligible for a Certificate, Part 139 requires the development of an Airport Operations Manual (see Attachment I) which further requires, among other things, that the airport operator "promptly" remove from runway pavement areas such items as snow, ice, slush, standing water, or other contaminants (139.83); to prohibit the presence of piles of snow where they might present a safety hazard (139.85); and to accomplish runway and taxiway condition checks on a periodic basis to insure that there are no hazardous conditions prevailing (139.91). Ordinarily, runway safety checks are made at least daily and at many airports are made three times a day, seven days a week. During inclement weather, these inspections are increased to insure that the condition of the runway is known at all times. (A plan to deal with snow and ice is included in Attachment I as Appendix II; it is currently undergoing some revision.)

Beyond the observation and control, there is the further obligation of reporting (139.69). Using the system known as NOTAMs (Notice to Airmen), all users of the national airspace system are advised as to temporary or permanent changes in the condition of the principal components of the system. This includes airport runways and their associated subsystems such as lighting and instrumentation. Criteria for the issuance of NOTAMs are prescribed by the FAA and are followed nationwide. Whenever snow or ice is present on an air carrier runway, a NOTAM is filed by the airport operator describing its present condition. In this manner, users of the system both locally and nationally are made aware of changes as they occur on a moment-to-moment basis. An example of a NOTAM originated by the Stapleton Operations Section is reproduced below:



STAPLETON INTERNATIONAL AIRPORT

NOTICE TO AIRMEN

PERMANENT NOTAM # ________ TEMPORARY NOTAM # N-12-27

CANCEL NOTAM N-12-24
R/N 17L/35R = CENTER 75'= PATCHES OF DRY
SNOW UP TO 1/8". BRAKING ACTION GOOD BY
DECELEROMETER. EDGES HAVE UP TO 1/4" DRY
SNOW/ICE. BRAKING ACTION FAIR TO POOR ON
EDGES

SENT BY		CANCELLED BY
Bob Gates	Opers. Supv.	BC
TNR	Tower	TNR
FSS	F.S.S.	RD
19 DEC 80	Date	19 DEC 80
1802Z	Time	2116Z
BG	Log Page	MR

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Revised Form 84 (SIA 12/77)

During times of changing runway conditions, measurements of runway condition are made by the airport operator using several techniques. Frequently, an Airport Operations vehicle, driven by an airport employee and often accompanied by an airline Snow Committee representative, will make both an inspection and braking observations. Some airports use a James Brake Decelerometer while other airports may use a mu-meter to evaluate runway friction coefficients. While all give some representation of the braking characteristics at a given moment, none exactly typify the response experienced by a large aircraft. For this reason, pilot reports are often used by FAA tower personnel to supplement official runway conditions as disseminated by the airport operator.

As noted above, one of the airport operator's responsibilities is to remove runway contaminants, including snow and ice. High-speed brooms work well for small amounts of snow (if slush is not a factor) and large plows and snow blowers are effective in removing large amounts of snow. None of these are effective with frost or ice build-ups. Over the years, numerous means have been tried at various airports to remove ice and frost with varying degrees of success. Small jet engines have been mounted on trucks with limited success and at high cost. Chemical compounds, such as urea, have found greater success and wider acceptability. Sand mixed with glycol has also been used with considerable success under certain conditions. Grooved runways are very helpful in removing rapid build-ups of water such as may occur during a series of heavy rains. Prudent airport operators assess current and forecasted weather conditions and make judgments with respect to the placement of chemicals and sand, bearing in mind the range and duration of their effectiveness. At Stapleton International Airport, for example, urea is regularly spread on runway surfaces at the start of a storm to maintain the operational status of that runway for as long as possible. If the temperature does not fall below 15° or 20° F, and if snowfall does not accumulate too rapidly, additional applications of urea may be adequate to maintain a clear runway. Should the temperature fall rapidly or snow accumulate beyond the capability of the urea to melt it, its condition will be carefully monitored. At a point beyond which airline operating manuals will no longer allow its use, and if its use is still needed, the runway will be closed by NOTAM and snow removal crews will go to work.

It is important at this point to note that a very clear line separates the responsibility of the airport operator from the aircraft operator as it regards using a runway under changing conditions. I have explained that it is the airport operator's obligation to report runway conditions in an accurate, timely fashion. It is also his obligation to remove snow and ice promptly. However, there is no magic wand available to an airport operator. I am sure the committee can appreciate that severe snowstorms often run for days, requiring extensive amounts of time and equipment to clear, and often requiring snow removal from the same runway on numerous occasions. Clearly, it is not possible under these circumstances to have perpetually clear runways; the airport operator does his best with what he has.

From the aircraft operator's perspective, his use of an airport runway depends entirely upon the Federal Aviation Regulations under which he is operating. Commercial airlines are required to have their own operating manuals, derived in part by performance capabilities of the aircraft as set forth by its airframe and engine manufacturers, the FAA, and the airline itself. The net effect of these operating manuals may be to preclude the use of a particular runway under particular weather and/or runway conditions. On the other hand, private or noncommercial aircraft may use a runway whose condition at any moment might preclude its use by a commercial operator. For this reason, airport operators are reluctant to close runways if they are usable by any segment of the broad spectrum of aircraft operators and (unless plowing or deicing) are likely to do so only when extreme conditions exist. An example of an extreme condition would be a freezing drizzle that suddenly turns to ice on all paved surfaces, or a blizzard condition, both of which make hazardous the operation of any aircraft, even taxiing aircraft, and airport vehicles.

In summary, aside from providing well-designed and safe operational surfaces in the first place, the airport operator has the obligation to maintain these surfaces in safe and usable condition. The federal grant-in-aid process stipulates continuous maintenance as a condition of grant receipt and FAR Part 139 provides definitive guidelines to insure that this condition is met. Airport operators have the never-ending obligation to observe and report accurately and timely the condition of all otherwise open and usable runways, particularly during the periods of inclement weather. They also have the obligation to clear the runway of contamination as promptly as possible. Short of an overall emergency condition resulting in a closure, they do not have the obligation of determining what aircraft operator may use such a runway or the conditions under which it may be used.

Thank you for the opportunity to present our views.

attachments 2

March 9, 1982

Mr. Glickman. Mr. Gore?

Mr. Gore. Thank you very much, Mr. Chairman. I will be brief because the hour is getting late. I am wondering about the distance-to-go markers. Do you think that is a good idea, and would that be too expensive to install at an airport your size, Mr. Wronkoski?

Mr. Wronkoski. No, I do not feel they are too expensive to install. We used them in the military, and I flew B-47's, which is a six-jet bomber, and I found them very useful.

Mr. Gore. So you think they would be a good idea?

Mr. Wronkoski. Yes; I think they would. I did not like that last one that said, "Our Father who art in Heaven." Yes, they give you a good idea of how much runway is left.

Mr. Michael. I think it is a bit of a tinkering, and it might be what some of the people would call plussing.

Mr. Gore. Plussing?

Mr. Michael. A slight additive to the system. I really do not think they are going to be of major significance in the overall scheme of things. If the weather is bad enough to begin with that you are having trouble seeing the runway markings, if the snow is coming down heavily, the chances are the pilot is trying to pay attention to keeping that airplane going right down center line, and he is not looking off right or left. One of the other guys is looking at the instruments as well. They are nice to have, particularly on deceleration as well, but I do not think they are necessary items in terms of overall safety.

Put it the other way around. If they had been, I am sure ALPA would have been on our backs a long time ago to have them in there. They are nice, and they are useful, but I wonder sometimes how the public sitting in the airplane reacts when they see it going "5," "4," "3," "2," "1" out the window. They are OK. I would not oppose them.

Mr. Gore. They will not be able to see them sitting backwards.

Mr. Michael. Yes, they can. They see them going the other way.

Mr. Wronkoski. It is written on both sides.

Mr. Gore. Well, it would be "1," "2," "3"——

Mr. Michael. As long as they know it keeps on going, they are in good shape.

Mr. Wronkoski. I agree with Mr. Michael. The main reason we used them was for extremely heavy takeoffs. That is when they were useful.

Mr. Michael. But in really bad weather, snow, ice, or heavy rain, they are not useful.

Mr. Gore. You cannot tell what the effect might have been with Air Florida. Of course, that is a hypothetical.

What about these friction testers? I think your response, if I could judge from your statements, would be that you do not have the money to buy these things. But let us assume, Mr. Wronkoski, that they are put on the ADAP list, and we get ADAP back to its intended form. Then what? Do you think it would be a good idea to have those?

Mr. Wronkoski. Not really, because I know of several medium-hub airports which have them, and they are sitting in the barn and they cannot maintain them.

Mr. **Gore**. Do you know of anybody who has the SAAB system?

Mr. **Wronkoski**. No, I do not, not SAAB. I believe most of those I know have MU meters, I believe.

Mr. **Gore**. This is a new system that consists of a car with a wheel built into it that serves as the MU meter, and you just drive it out on the runway and it gives you a reading, and you correlate it with the aircraft performance and transmit that data to the pilot, and he gets an indication of whether he is going to get traction, friction, or not.

Mr. **Michael**. I think, Mr. Gore, you put your finger right on the key word: Correlation. The James brake decelerometer is a fine device that sits inside the vehicle. You step on the brake and watch a needle based on how much friction you have, and you have some number that you can report. If you put that on the NOTAM, and the NOTAM comes up on air terminal information service, or maybe it goes out over local or ground control, and the pilot says to himself, 'What's 32? I don't know what 32 is." Furthermore, '32" to a jet operator might be much more critical than 32 to a turbo prop operator, where you have those big reversible fans out front.

Mr. **Gore**. If you had correlation with each aircraft's performance—and we had testimony from the Air Line Pilots Association that their consultant has already done that, and they believe that if the FAA will check his methodology they will find it valid. That is a string of assumptions. But assuming that the correlation data are found, then it might be useful to a pilot; is that right?

Mr. **Michael**. I agree, particularly during high-density operations on a specific runway where the conditions do not change much between one operation and the next. In fact, if you are looking for research suggestions, I think that is one where some attention could be given: A really solid look at the measurement of runway friction, not only during snow and ice but other kinds too.

Back when FAR part 139 was first being put together, there was more concern than there is now about slippery runways during wet conditions, which eventually was translated into a lot of grooved runways. But they were concerned about slipperiness based on rubber buildup. One of the efforts made in part 139, some 10 years ago, was to see if you could not have some quarterly or periodic measurement of all of the runway conditions, under both wet and dry, to get a difference in how braking occured during those occasions and report it on a permanent NOTAM, which carries a certain amount of logic to it.

What fell apart was, there was no systematic way to do that which was understandable and translatable by the users.

Mr. **Gore**. I have enjoyed your statements immensely, and I appreciate them, too.

Thank you, Mr. Chairman.

Mr. **Glickman**. I have just one question.

Mr. Michael, you intrigue me with your concept about airport control and operational control. If I am at Stapleton, and the ceiling is at 100 feet, and visibility is one-eighth of a mile, it is snowing, and I am a United Airlines pilot who wants to take off, can you stop me from taking off?

Mr. **Michael**. Only if I close the runway.

Mr. **Glickman**. But you have the authority to close the runway?

Mr. **Michael**. Yes. I am the representative of the municipality that owns the real estate. I can, therefore, using the power vested in me, close that runway at any time I as the airport operator choose. I do not like to do so, but I will if it is necessary.

Mr. **Glickman**. Now, what authority do the controllers in the terminal have with respect to me, Captain Glickman, wanting to take off.

Mr. **Michael**. They can deny you clearance to take off, which means that they do not want you in the system. However, if the captain chooses to take off, for reasons known best to him, all the FAA can do is file against him. But he will take off, if he wishes.

Mr. **Glickman**. Mr. Wronkoski?

Mr. **Wronkoski**. In essence, what happens is this. We, the airport operators, control the ground; the air traffic controller controls them once they leave the ground. He cannot override us and tell the pilot he can take off if we close the runway.

Mr. **Glickman**. There had to be some line of demarcation there. Somebody has to be ultimately in charge. You indicate that the step you can do is to close the runway. How often have you closed runways at Stapleton during this winter?

Mr. **Michael**. Zero.

Mr. **Glickman**. Zero times?

Mr. **Michael**. A runway from time to time gets closed for snow removal activities.

Mr. **Glickman**. But you have two parallel north/south runways.

Mr. **Michael**. Yes. The airport as a whole is not likely to be closed, unless snow is very, very heavy or the weather very serious. We have closed Stapleton twice in the last 10 years.

Mr. **Glickman**. I know that is an issue that is being raised in the current NTSB hearings, as to who is responsible for which decisions: airport operator, pilot, and controller. It is an issue that we may wish to explore further.

We thank you very much for your testimony.

[Material follows:]

March 3, 1982

STATEMENT OF MR. EDWARD J. WRONKOSKI

Mr. Chairman and Committee Members:

I wish to thank you for inviting me to speak and offer my views at your hearing on Aviation Safety Research and how the Annual International Snow Symposium has been and is still working on aviation and aircraft safety program during winter operations.

First, a little history of the Annual International Snow Symposium. Back in mid 1960 a handfull of airport managers and manufacture representatives met to discuss the needs of airports located in the snow country and to exchange ideas of the best ways to remove snow and to control ice at these airports. All of these people were members of the Northeast Chaper of the American Association of Airport Executives. Mr. Wiley Post, Manager of A-B-E (Allentown-Bethlehem-Easton) Airport, was appointed chairman, a position he still holds. The first symposium was held in the year 1967 with an attendance of 200. This has grown over the years where the attendance now exceeds 300 from all snowy parts of the U.S. and ten foreign countries.

Now in its' 16th year, this four day series of general sessions, workshops and informal gatherings finds hundreds of individuals from all segments of the aviation industry gathered together to exchange sound ideas, tested procedures and efficient techniques for coping with snow, slush and ice removal at airports. Attendees are shown and told how they can minimize cost in the battle with the winter elements and avoid costly operating delays for their airport users and air travelers. Ideas, questions, challenges or experiences are shared for the benefit of all who want to learn. Sessions are broken down for large and small airports as small airport do not have the money for the numbers and variety of equipment and materials used at the larger airports. Small airports are also limited in the quantity and quality of personnel utilized to accomplish these important safety procedures. A typical small airport may have anywhere from one to a dozen employees to accomplish the same amount of snow removal as a larger airport which has a larger number of employees to accomplish the same task.

All airport operators are interested and concerned about safety programs for if there is any one thing he or she does not want is an accident of any type. Your typical small airport is constantly up against daily problems in snow removal. Every user wants the airport runways, taxiways and ramp areas clean and dry at all times they want to operate and we try to do the best we can with limited manpower and resources. Your user, although aware of your problems, still pressure you into having the task completed when they need it. Time of day or night makes no difference, lack of personnel and equipment makes no difference, our cost does not interest the user.

Let us look at some of the programs now in progress. First, the Friction Measuring Equipment. This is a fantastic piece of equipment that tells us how good or bad our runway condition is. We already know it it's good or bad by just driving on it with any vehicle. Runway conditions may constantly change during certain winter conditions and the reading you receive now may not apply one half hour later. My main objections to this type of equipment are:

1) Cost of Equipment
2) Maintenance and calibration
3) Qualified personnel to operate and interpret

Runway grooving has been a good asset in providing and maintaining good runway surface conditions during winter operations or wet any season operations.

Speaking for myself, as a small airport manager, I can tell you that what we need is improved materials and equipment that will remove snow, slush and ice. Maybe a new type of pavement that would provide better traction under icing conditions. It appears to me that European Airports are placing more emphasis on means to eliminate or control winter conditions where we are looking for methods to tell us how bad our airfield conditions are.

The real problem for small airports is that they are expected, and in fact demands are made on them, to maintain airfield safety conditions that they cannot afford. Take my airport for example; it is owned and operated by the County of Chemung with a population of approximately 100,000 people. About 1 out of 10 of these people will use the airport once a year for air travel. The other nine taxpayers refuse to support a facility that in their opinion only is used by 1 out of 10 people in the county each year. They do not realize or understand that the vast majority that use our facility are business and industry that is vital to the community existance and without the air facility or a means of providing transportation the area economy and growth would deteriorate further.

In 1970 Congress passed a bill called ADAP (Airport Development Aid Program) where only the airport users were taxed to provide funding to improve airport facilities. The program had inequities but was excellent and showed signs of improving until 1980, when there was a surplus of over 4 billion in the trust fund, the flow of money was cut to a minimum or non-existent. Now the user fund was cut to 5% and is not going into airport improvements but into general funds. Funds are being used to finance FAA and I doubt if any airport operator objects to this as we feel that there could be sufficient funds for both. Maybe not to fund an overgrown FAA that expanded far beyond its original intention. Airport Trust Fund money is not being used for the protection of the people who paid into it as Congress mandated. I know of no other government agency that is operated and paid for partially or in full by funds collected from the users. I take for example the highway funds, waterways and harbors or even the railroads. Congress will appropriate billions to the railroads each year but will not return to airports the funds that were collected as a user tax from the system. Without these funds airports will most likely go the same route as the railroad. Airfield pavements will deteriorate as the rail beds have, terminals will become obsolete and deteriorate as railroad stations have.

There is talk now of taking the large airports out of the ADAP Program and allowing them to collect a reasonable head tax that may be used as they see fit to maintain and operate their airport. Large airports already are profitable operations. Small airports would stay in the program and continue to receive entitlement funds but would be told by the Congress or FAA as to how we can use them. Example of waste in this type of thinking is: We built a 5,200 foot and a 7,000 foot runway at our airport with several million dollars of ADAP funds. These runways with proper care and preventative maintenance would be useful for 20 years; however, we have no funds for this purpose. If we received some funds for maintenance we would not have to come back in five to ten years and ask for millions more to replace a non-maintained airport. Small airports should be given grants (from user funds) to maintain pavements, lights, maintain or replace required vehicles, snow/ice removal materials such as hot sand, urea, U-car or any other suitable snow or ice control materials. On the other hand small airports never have received sufficient funds to improve their airports to the safest possible condition. This was and is primarily due to the ADAP entitlement procedure which makes small airports rely on discretionary funding which in most cases was never available. Airport safety costs are basically the same for large and small airports but funds for small airports have never been in sufficient amounts to be operated safely. Small airports cannot be operated and maintained like a large airport on generated revenues for many reasons such as:

1) Less flights with smaller aircraft which means less revenue.
2) Lower landing fees than large airports. (If we tried to collect a landing fee that large airports charge the airlines laugh and threaten to cut our service lower or out.)
3) Mandated Federal programs such as Security, C/F/R and Operation Manual directives.
4) Lower space rental fees than larger airports receive for the same reason as No. 2 above. Tennants at small airports also use less space.

In conclusion, my comments would be "yes" we need continued research in safety procedures and equipment for aircraft and airports, but not devices that lawyers can use in court as evidence for law suits. What we need is research in methods and materials that can be used to prevent or control unsafe conditions at a cost that small airports can afford. To date, the Snow Symposium offers many opportunities to all airports with its exchange of ideas, procedures and different deicing materials used along with proper timing and application of said materials.

Thank you for allowing me to present my feelings and thoughts to you on this very important aspect of airport and aircraft safety.

Edward J. Wronkoski
Airport Manager
Chemung County Airport
3350 Sing Sing Road
Horseheads, New York 14845

March 3, 1982/mh

Mr. **Glickman**. We have one final witness today, Matthew Finucane, director of the aviation consumer action project, accompanied by Cornish Hitchcock. We appreciate your testifying, and your entire statement will appear in the record. It may be useful for you to summarize, if you can.

STATEMENT OF MATTHEW H. FINUCANE, DIRECTOR, AVIATION CONSUMER ACTION PROJECT, ACCOMPANIED BY CORNISH F. HITCHCOCK, LEGAL DIRECTOR, AVIATION CONSUMER ACTION PROJECT

Mr. **Finucane**. Chairman Glickman, Chairman Gore, and members of the committee, thank you very much for this opportunity to appear before you today.

As a nonprofit group active in the field of aviation safety, we were deeply saddened and troubled by the recent crash at Washington National. We were particularly troubled by reports that most passenger deaths appear to have been caused by seats that broke loose and propelled the passengers throughout the cabin, where they then hit some fixed object.

The problem of seats breaking loose in takeoff and landing accidents is one that the scientific community has been trying to get the FAA to solve now for 30 years. I am sure you have heard today already that seats and tiedowns are much weaker than the human body and fail before the human body does. I am sure you have heard that there has been 30 years of research calling for stronger seats. But what you might not be aware of is that the FAA's own staff has been calling for over a decade for stronger, energy-absorbent, dynamically tested seats.

If you will turn to page 6 of our testimony, you will see a chart showing the FAA's current seat strengths and seat tiedown strengths. You will see next to those a 1969 recommendation by the FAA's own staff calling for seats that are roughly twice as strong as they currently are now. Next to that, you will see a 1978 recommendation, again by the FAA's own staff, calling for seats twice as strong as they currently are now. Just as a way of comparison, I have put next to that the current Army standards for troop seats, which are in some cases 3 to 10 times as strong as current aircraft seats. Also, by way of comparison, I should note that car seats are from two to three times as strong as current aircraft seats.

We believe that the FAA is using research as an excuse to avoid requiring stronger, energy-absorbent seats, because the airlines do not want to pay for developing, testing, and installing improved seats. While such costs concerns are objectionable in the first place, the irony is that improved seats would not really cost that much more.

For example, in 1978, the staff report from the FAA recommending the stronger seats—and I should note that this report included a proposed standard that could have been put into effect that day, with all the underlying technical data—that report stated that a survey of seat manufacturers showed that currently available seats are already in some cases designed to withstand twice the force required by the FAA. The report said that "reliable dynamic test facilities are available in a quantity sufficient for minimizing the cost of dynamic testing." The report said that although initial development costs would increase, "the increase would be amortized and likely to produce a small incremental cost" over a series of seats. Finally, the report said that while the airlines contend that seat weight would increase and reduce payload or increase fuel costs, "the incorporation of energy-absorbing features can reduce seat weight."

If the FAA appears intent on doing further research in this area, and the NTSB has questioned the need for any further research prior to any rulemaking, we urge the committee to at least make sure that the FAA keeps its program on schedule. Annual reviews are very useful, and we think the committee is doing an excellent effort in this area by having this hearing today.

Another area where FAA research is holding up the implementation of improved safety materials is in the area of post-crash fires. The FAA is working on antimisting kerosene, but it is not going to be available for nearly a decade. As for short-term efforts to stop the post-crash fire problem at its source, progress in this area has also been disappointing. In mid-1980, the SAFER Committee, on which we were represented, made short-term recommendations for rulemaking in the area of fuel tank vent protection, engine fuel supply shutoff, and modification of the flammability test now in use.

All of these actions should have been completed by now, but they have not been. There has been no notice of proposed rulemaking. They just have not done a thing. We think that 1½ years after that SAFER Committee report, the FAA is 1½ years behind in improving post-crash fire standards.

Another area I would like to touch upon briefly is the fact that cabin materials give off tremendous amounts of smoke and toxic fumes in post-crash fires. The FAA has no standards in this area. In 1977, they awarded a contract to McDonnell Douglas to develop standards. They gave them $400,000. McDonnell Douglas has given them the standards for smoke and toxic gases, and according to the FAA, in a quote from Science magazine, "It was a good effort, but it is not the final answer."

If we are going to have to wait for the final answer from the FAA before we get smoke and toxic gas standards, the question then becomes: Are there any materials that can be placed in the cabin today? We think there are. As the NTSB has testified, there are seat blocking layers for aircraft seats that can increase passenger evacuation time by 50 seconds. We think they should be installed now. Of course, rather than require these materials, the FAA is doing research into durability.

Concern for airline costs, not safety, is once again keeping a known solution on the shelf.

In conclusion, I again want to thank the committee for holding these hearings, and we think that this kind of oversight is absolutely essential if you are going to keep FAA research from just slipping and slipping for decades and decades, as it has done in seats, fires, collision avoidance systems and in many other areas.

[The prepared statement of Mr. Finucane follows:]

FAA RESEARCH IN AIRCRAFT CRASHWORTHINESS

Testimony of Matthew H. Finucane, Director, Accompanied By
Cornish F. Hitchcock, Legal Director
Aviation Consumer Action Project

before the

Subcommittee on Investigation and Oversight
and
Subcommittee on Transportation, Aviation and Materials
Committee on Science and Technology
U.S. House of Representatives

9 March 1982

Chairman Gore, Chairman Glickman, Members of the Subcommittees:

On behalf of the Aviation Consumer Action Project (ACAP), the only non-profit consumer group working full time on aviation issues, we appreciate the invitation to appear before you today to discuss Federal Aviation Administration research in the area of air carrier crashworthiness.

Since its founding in 1971, ACAP has long been interested in effective air safety regulation. We have initiated and taken part in various FAA rulemaking proceedings, taken part in FAA hearings and advisory committees and been designated a party at hearings by the National Transportation Safety Board into the probable cause of air carrier accidents.

Many passengers today who could be surviving low impact crashes are dying unnecessarily because of seat and seat restraining failures and from post-crash fires, which are accompanied by toxic gases emitted by burning cabin materials. These seat failures and fires are occurring because of FAA standards which are far behind the state-of-the-art for seat design, seat testing, cabin materials and materials testing. The FAA's position that further research is needed in many of these areas before new standards are written is a cruel hoax on passengers that is allowing the FAA to ignore known problems and known solutions. As the FAA's staff said in a 1978 report recommending improved seat strength and dynamic testing of seats:

> Research can provide answers, but it nearly always raises additional questions. If the answers that are known are not applied, then research efforts are wasted.[1]

SEATS

Passenger deaths as a result of seat failures is all too common and has been widely documented. While the idea of a plane crash often brings to mind a catastrophe with no possibility of survival, the NTSB recently documented 77 survivable or at least partially survivable accidents in just the last ten years involving aircraft of 30 seats or more.[2] Most of these were take-off and landing accidents and all involved forces which should not have killed a passenger properly restrained with a lap belt.

Unfortunately, 1850 people were killed or injured in these crashes.[3] Forty-five of the crashes involved failures of cabin furnishings, usually seats.[4] Typically, the seats break loose from the floor, propelling passengers about the cabin, pinning them, and blocking aisles. In addition to direct injuries from being thrown about the cabin, passengers who are trapped by broken seats or blocked exits can be killed by the post-crash fire.

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[1] Initial Project Report, Energy Absorbing Seat Design, Project No. 70-599-120A, Mike Monroney Aeronautical Center (August, 1978).

[2] National Transportation Safety Board, "Cabin Safety in Large Transport Aircraft," NTSB-AAS-81-2, p.3, (September 9, 1981).

[3] _Id._ at 3.

[4] _Id._ at 7.

The reason that passengers are killed in crashes involving forces that should not kill them is that aircraft seats, designed to FAA standards written in 1952, and are very weak compared to the strength of the human body, and fail under forces the human body can withstand. The relative strength of the human body and aircraft seats is described below in terms of the force of gravity.

FORCES HUMAN BODY CAN WITHSTAND[5]	
Forward	20-25g
Downward	15-20g
Sideward	10-15g
Upward	20g

FAA SEAT STRENGTH STANDARDS[6]	
Forward	9g
Downward	4.5g
Sideward	1.5g
Upward	2g

Since the human body is stronger than the seat, the seat does not protect the passenger. Rather, in actual crashes the seats break loose and the passenger, who is then propelled throughout the cabin and crushed, ends up protecting the seat. This problem has been known for thirty years in the scientific community, and the FAA's own staff has on several occasions called for stronger seats. Here are a few highlights of the research and calls for stronger seats over the years:

1958 Mosely and Zeller term the dislodgement of aircraft seats and occupants "a most prevalent injury factor" and advocate further upgrading of seat strength regulations [Relation of Injury to and Direction of Deceleration in Aircraft Accidents, 29 J. Av. Med. 739 (1958)].

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[5] 14.C.F.R. §25.561 and 25.785(a) provide that passengers should not suffer serious injury in landing conditions involving these forces taken separately. 14.C.F.R. §25.785(i) provides that seats be designed for an occupant weight of 170 pounds under these forces. 14.C.F.R. §25.785(i)(3) provides that the attachment of the seat to the floor and teh seat belt to the seat must be equal to the above described forces multiplied by 1.33. TSO-C39(a) allows for static testing of seats.

[6] Conservatively estimated in the 1981 NTSB Study, supra n.2, at.3.

1962 Haley, in a thorough study for the U.S. Army, states that "failure of the tie-down chain has been the major cause of unnecessary injuries and fatalities in numerous aircraft accidents." [Personnel Restraint Systems Study: Basic Concepts, United States Army Transportation Research Command: TCREC-TR-62-94 (1962)].

1962 The CAB (predecessor of the NTSB) concludes that seat failures in a September 23, 1962 low-speed ditching of a Constellation into the Atlantic prevented at least some of the 28 persons who died from escaping and tells the FAA that "an increase in the minimum level (of crashworthiness) is long overdue." The FAA responds "We concur with the views contained in (your) recommendation relative to adequacy of seat tie-down. We wish to assure you that the need for necessary studies relative to crash load factors and dynamic seat testing criteria is clearly recognized and that these studies are being expedited by our Aircraft Development Service consistent with available manpower and funds."[7]

1962 Swearingen, Hasbrook, Snyder & McFadden state that "current seat tie-down requirements are inadequate." [Kinematic Behavior of the Human Body During Deceleration, 33 Aerospace Med. 188 (1962)].

1965 Turnbow et al. term the FAA's seat strength rules "inadequate" and state that "present-day transport seats, designed for a 9g forward load, have failed and caused the deaths of occupants who otherwise might have survived." [73 Soc'y of Automotive Engineers J. 38 (June, 1965)].

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[7] Id. at 1.

1967 Turnbow et. al. recommend 20-25g forward, 15-20g downward, 15-20g upward, and 10-15g sideward based upon extensive crash testing for the Army. [Aircraft Passenger-Seat System Response to Impulsive Loads" U.S. Army Aviation Materials Laboratories TR No. 67-17 (August, 1967)].

1969 In response to an FAA Notice of Proposed Rulemaking 69-33 proposing increased standards for upward, sideward and rearward forces, the FAA's Office of Aviation Medicine recommends that seat requirements be increased to 20g in the forward, downward, and upward directions, and 10g in the sideward direction.

1969 FAA technical center (NAFEC) recommends that dynamic testing of aircraft seats be a requirement of the regulations and provides a test specification derived from crash tests of a Constellation. [Rpt. No. NA-69-5 (May, 1969)].

1973 S. Desjardins states that "aircraft can be designed to provide crash protection to occupants at relatively little penalty to weight and cost" and "seating and restraint systems should have the strength required to remain in place until the surrounding structure collapses." [Vehicle Crashworthiness in Numerical Methods in Structural Mechanics (1973)].

1977 ACAP, the Flight Attendants, and the Flight Engineers International Association formally petition the FAA to increase the strength of seats and their tie-downs, require dynamic testing of seats, encourage the use of energy-absorbing materials, and consider requirement of rearward facing seats. The petition is ultimately denied in 1981.

1978 FAA research staff at the Mike Monroney Center issue a project report recommending giving airlines the option of using a dynamic test criteria, or increased static test values more representative of actual crash loads (18g forward, 12.6 downward, 5g upward, 3g sideward, and 4.5 rearward). This static test would allow for energy absorbing material. [Energy Absorbing Seat Design, Project No. 70-599-120A (August, 1978)].

1981 A major NTSB review of cabin safety describes ten years of passenger injuries as a result of seat failures and recommends that the FAA's thirty year seat standards be upgraded to reflect the state-of-the-art, including requiring dynamic testing.[8]

Perhaps the best way to summarize these decades of research and recommendations is to compare the current FAA standards with what the FAA's own staff has recommended in 1969 and 1978, and what the Army currently provides in its standards for troop seats.

COMPARISION OF EXISTING STANDARDS WITH FAA STAFF RECOMMENDATIONS AND ARMY STANDARDS

	Current FAA	1969 FAA Aviation Medicine Recommendations	1978 FAA Mike Monroney Center Recommendations	Current Army Standards for Troop seats[9]
Forward	9g	20g	18g	30g
Downward	4.5g	20g	12.6g	48g
Sideward	1.5g	10g	3g	20g
Upward	2g	20g	5g	8g

Given the recommendations of its own staff, the NTSB, and the scientific community, why is the FAA refusing to upgrade its seat standards? If the FAA has any lingering concerns over the feasibility or cost of placing stronger, dynamically tested[10] seats in aircraft it need only turn to its own 1978 staff report which found that: (1) a survey of seat manufacturers showed that some currently available seat models are designed to withstand at least twice the forces required by the FAA standards;[11] (2)"confidence in dynamic testing has grown to the point where the U.S. Army specifies dynamic performance criteria for seats and safety belts;"[12] (3)"reliable dynamic tests facilities are available [at four U.S. auto manufacturers and at six independent facilities] to aircraft seat manufacturers, in a quantity sufficient for minimizing costs of dynamic testing;"[13] (4)although initial development costs would increase (for seats designed to higher static standards or dynamically tested) "the increase would be amortized and likely produce only a small incremental unit cost increase;"[14] and (5) while the airlines contend that seat weight would increase and reduce payload or increase fuel costs if new standards were issued, "incorporation of absorbing features can reduce seat weight."[15]

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[8] Id. at 3, 32.

[9] Cabin Safety: "Safer Committee" Update [Aircraft Passenger Seat Structural Design): Hearings Before the Subcomm. on Oversight and Review of the House Comm. on Public Works and Transportation, 96th Cong., 2d Sess. 340 (1980)] (Statement of George T. Singley, Applied Technology Laboratory, U.S. Army Research and Technology Laboratories, Fort Eustis, Va.). High downward of forces are prescribed because of Army use of helicopters. Current standards for automotive seats also exceed the requirements for aircraft seats by a factor of two to three.

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[10] Although the legislative history of the Federal Aviation Administration Act of 1958 indicates that cost should only be an incidental concern to the FAA, the FAA has historically been quite receptive to industry concerns about the cost of safety improvements and the new FAA head, J. Lynn Helms, has promised to cut FAA regulations in order to reduce industry costs.

[11] Regulatory Standards and Analysis Branch, Mike Monroney Aeronautical Center, Initial Project Report, Energy Absorbing Seat Design, Project No. 70-599-120A, p.5, (August, 1978).

[12] Id. at 18.

[13] Id. at 18.

[14] Id. at 26.

[15] Id. at 26.

During Congressional hearings in 1980, the FAA staff explained its opposition to improving seat standards on the grounds that "it is simply not true that the human body has been shown capable of withstanding significantly more acceleration than current seats are designed to withstand."[16] This claim flies in the face of thirty years of scientific research and was subsequently retracted by the then head of the FAA, Langhorne Bond, in response to a critical follow-up letter from a member of the Congressional Committee. Bond said "it is not the position of the FAA that human tolerance with lap belts is so low that strengthening the existing seat standards would be pointless."[17]

At the same hearing, FAA staff alleged that aircraft floors are so weak that there would be no point in improving seat strength.[18] In response to the same follow-up letter from Congress, Langhorne Bond retracted this statement and said:

> It is not the position of the FAA that current fuselage strengths are so low that any strengthening of the seat would be pointless. For airplanes presently in service, some local strengthening of the floor structure would probably be required if the static load factors were significantly increased. This would be within the present state-of-the-art and is technically feasible.[19]

According to the 1981 NTSB study on seats, the Army's Aircraft Crash Survival Design Guide provides detailed information on how to easily improve seat tie-downs including: "a plastic hinge at the seat-to-floor track attach point . . . which will deform without failure up to a certain point as the floor is displaced . . .;" "a ball and socket joint at the seat-to-floor track attachment . . .;"

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[16] Cabin Safety hearings, *supra* n. 9, p.391, (testimony of Walter S. Luffsey, FAA Associate Administrator for Aviation Standards).

[17] *Id.* at 683.

[18] *Id.* at 389.

[19] *Id.* at 684.

and "small aluminum collars on the seat track tie-down bolts between the nut and the floor . . .(which). . .spread the load."[20]

The FAA staff further argued at these hearings that making seats stronger would make the seats more rigid, thereby transferring greater loads to the passenger and causing more injury.[21] However, after it was pointed out in the Congressional follow-up letter that a seat can be strong without being rigid, Bond subsequently conceded that "impact resistance and energy absorption can both be designed into seats" and that "strength and rigidity are two different engineering concepts."[22]

Are there any valid reasons not to increase the seat strength standards today?

We do not believe that more research is needed before standards for stronger, dynamically tested seat standards can be written by the FAA. While research is always useful, the FAA should not reinvent the wheel or use research to ward off regulatory change. After all, thirty years of research has already been done and not all of it has been in the lab. Thousands of people have died not knowing that they are unwitting research subjects in one of the most shocking FAA experiments ever conducted -- to see whether standards written in 1952 can be safely used until the year 2000. They cannot be, and this is an experiment that should be brought to a halt immediately.

FAA, military, and industry research in the 1960's, including the crash-testing of a Lockheed Constellation and a DC-7, showed that strong, dynamically tested seats are necessary and feasible. Instead of using this data, which has been refined from actual experience over the ensuing decade, the FAA feels that crash testing is needed once again.

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[20] 1981 NTSB Study, *supra* n.2 at 26, 27.

[21] *Id*. at 391.

[22] *Id*. at 685.

According to the NTSB, the FAA wants new data because it feels that the crash testing on the Constellation is outdated and does not represent today's actual crash environment. And yet, the Board points out, the FAA plans to do its crash test in 1985 on a B-720, a narrow-body aircraft with four wing mounted engines that resembles a B-707 and was certified only seven years after the DC-7. We share the Board's skepticism that such a crash test really will provide the FAA with data it will find more acceptable.[23] And we share the Board's concern that if we wait for the FAA to finish its research, we may not see better seats in aircraft until the year 2000.[24]

Since the FAA appears intent on doing the research prior to any rulemaking, we urge the Committee to at least make sure the FAA keeps its research program on schedule. The FAA denied our petition for stronger seats in January, 1980 on the grounds that further research was needed, and issued a report in June, 1980 outlining its schedule for research, including: integration of a three dimensional computer program which simulates the response seat, occupant, and restraint system to a crash environment (SOMLA) with a mathematical model for crash simulation of aircraft structures (DYCAST) by FY-1981; performance of full-scale verification tests and documentation of this integration by FY-1981; utilization of the results of this verification to design, construct, and test new crashworthy seats by FY-1984; and to establish new design standards, test criteria, and procedures for crashworthy seats by FY-1984.[25]

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[23] 1981 NTSB Study, supra n.2 at 30.

[24] Id. at 30. Obviously, it is difficult to quibble in the abstract with FAA efforts to find the perfect solution or a solution which looks at the seat strength issue as part of the broader question of crashworthiness of other conponents of the cabin and fuselage. The question is: at what price? Is long-term research to be carried out to the exclusion of more modest, short-term solutions as the FAA apparently intends in the seat strength area? Or is the agency considering short-range alternatives, mindful of the fact that research always begets more questions, and that funding for long-term projects may drop off as priorities shift from Congress to Congress and from Administrator to Administrator?

What we find particularly astonishing in the seat strength area is that the FAA's own staff developed a short-term approach to the seat failure problem, one that even the industry acknowledged would be low in cost. (see text citing to ft.11) Unfortunately, the FAA, which had our petition pending before it at that time, never considered this study and never made it public for almost two years until we filed a Freedom of Information Act request in 1980. Adding insult to injury, FAA never even mentioned this report -- whose conclusions were endorsed by the NTSB as a short-term approach -- when it got around to finally denying our petition in mid-1981 in favor of a mammoth, comprehensive crashworthiness research project whose benefits may not be seen by the travelling public until almost the end of this century.

If these schedules have changed, we urge the Committee to find out why.

POST-CRASH FIRE HAZARDS

In many accidents, people may survive the crash forces, only to be killed when fire breaks out. When a fuel tank is ruptured or breached, highly flammable fuel can be released in a fine mist. If ignited, it can produce a large fireball.

The severity of the post-crash fire problem is apparent from NTSB statistics, which show that fire can be expected in about 20 percent of all air carrier accidents involving passengers, and over the past 15 years, almost 20 percent of all accident fatalities can be attributed solely to the effects of fire. See testimony of NTSB Vice-Chairman Elwood Driver before the Subcommittee on Oversight and Review of the House Public Works Committee on "Aviation Safety" (Interior Compartment Materials) at page 5 (1979).

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[25] Federal Aviation Administration Technical Center, Report No. FAA-Ed-18-6, "Engineering and Development Program Plan, Aircraft Crashworthiness," at 18, 19, (June, 1980).

There are several threats if a fire breaks out. People may be killed by the fire itself. Secondly, the presence of fire can dramatically shorten the time available for evacuation. Finally, the fire may lead to combustion of cabin materials, which may then emit thick black smoke and toxic fumes -- such as hydrogen cyanide or carbon monoxide -- which make visibility difficult and can overcome passengers before they can evacuate promptly. The FAA has been aware of these hazards for a number of years, and with respect to cabin materials, has long had a standard for the flammability of such materials, but none for their propensity to emit smoke or toxic fumes.

These areas have long been of concern to ACAP, which filed rulemaking petitions with respect to the fire problem in 1972 and with respect to the smoke and fumes problem in 1973. The FAA in the mid-1970's proposed regulations in these areas and, at the conclusion of two public hearings in 1977 decided to set up an advisory committee to advise the agency on what should be done in the area. In mid-1978, the rulemaking proceedings were abandoned to wait for the report of the so-called "SAFER" committee, scheduled for release in mid-1980. As in the seat strength area, this decision led us to suspect that FAA was once again in search of the ultimate, perfect solution, no matter what the state-of-the-art and no matter what the nature of the short-term solutions which might provide greater safety today, not at some unspecified time in the future.

In analyzing the FAA's progress in the post-crash fire area, it is perhaps most useful to consider the problem first from the standpoint of reducing the risk of fire -- for, after all, if the outbreak of a fire can be prevented or retarded, that materially enhances the chances of swift evacuation and reduces the dangers inherent whenever any fire breaks out -- and then second, from the standpoint of reducing the hazards from cabin materials if a fire is, in fact, present.

With respect to the fire issue, FAA began working to validate the workability of anti-misting kerosene (AMK), an additive which is designed to reduce the fine mist of fuel which is given off when fuel tanks are breached, thereby reducing the chance of a fireball erupting at the crash scene. Experimentation has been going on at the FAA's Technical Center in New Jersey for the past two or three years to see if AMK will really work. The good news is that if AMK is feasible, it will probably be the most cost-effective way of diminishing the post-crash fire hazard. The bad news is that, under the FAA's current timetable, it will be 1984 at the earliest before FAA can initiate any rule-making proceeding on AMK standards, and thus the traveling public may have to wait until the end of the decade -- if we're lucky -- before any AMK additives are actually in the general usage of the industry.

As for short-term efforts to stop the post-crash fire problem at its source, progress thus far has been disappointing.

In mid-1980, the SAFER Committee, on which ACAP was represented, made short-term recommendations for rulemaking in the areas of fuel tank vent protection, engine fuel supply shut-off and modification of the flammability test now in use, which does not accurately measure materials which melt and drip away from the flame. All of these actions should have been completed or be near completion by now, but, to our knowledge, the rulemaking process has not begun, and no Notices of Proposed Rulemaking have appeared in the Federal Register.

If implementation of a rule to lessen the chances that a fire will ever start is thus far in the future, is there anything which can be done with respect to smoke and toxic gas? After all, even if it is difficult to control the outbreak of a fire, is there not something which can be done to reduce the effect of its by-products?

Here again, the FAA seemed inclined to put all of its eggs into the "comprehensive solution" basket, instead of exploring short-term approaches such as setting independent standards for smoke and toxicity based on the available state-of-the-art. Following the 1977 public hearings in this area, FAA awarded a $397,000 contract to McDonnell Douglas to develop a "combined hazard index" to evaluate a material from the standpoint of flammability, smoke and toxic emission characteristics. In the abstract, the concept of such an index may sound appealing, since cabin materials which are hard to burn (and which meet the FAA flammability standard) may give off large quantities of smoke or fumes and vice versa.

McDonnell Douglas did complete the study, but it is not clear whether the public will see any benefits soon. In a February

1981 issue of Science, it was reported that:

> Using a mathematical model developed at the University of Dayton and test instruments conceived at Ohio State University, the contractor created an index of cabin materials hazards expressed as a function of evacuation time: the less hazardous the materials, the more time passengers have to escape. The $400,000 index was initially seen as a useful tool for requiring the use or invention of safer cabin materials. FAA technical officials, who received the aircraft company's report several weeks ago, now say it was a good effort, but is not the final answer. Wayne Howell, the fire safety chief at FAA's technical center in Atlantic City, says that more work must be done to verify human survival limits . . . . "The contractor used the best fire model available, but it isn't good enough. We're going to have to run tests with primates exposed to these gases," an effort that will require at least another year. (emphasis added)

In other words, after four years and $400,000, the "combined hazard index" remains an elusive goal, and the FAA seems intent on pushing ahead with further research which cannot be traslated into life-saving standards for the foreseeable future.

Are there any short-term solutions which can be attempted in the cabin materials area? The answer is "yes." The National Transportation Safety Board has testified at prior hearings that there are safer materials which can be put into aircraft cabins today, and there are various steps which, while not providing a comprehensive solution in themselves, can buy some additional time for people who have to evacuate an aircraft after an accident where fire is a threat.

For example, one step is fire blocking layers placed around the flammable polyurethane seats used in aircraft. The FAA's Technical Center has found that these layers, placed around seat cushions can increase passenger evacuation time by as much as 50 seconds. Why not require their installation now? According to the Technical Center, a variety of options are available, including DuPont's Vonar III, and the lighter Celiox made by Gentex and Norfab made by Amtex. The Technical Center has added that the latter two materials "are aluminized fabrics used in steel mills and as a replacement for asbestos suits and gloves. The materials will not burn, even when molten aluminum is poured onto them."[26] In addition, International Harvester has "developed a resilient foam of polyimide, which is light and more fire-resistant than polyurethane" and "has concluded its own tests and intends to begin marketing its invention" in 1981.[27]

In brief, then, the history of FAA activities in this area is one that should make the public skeptical that prompt and effective action will be taken in the near future. In light of this record, we believe that Congress can play an important role, and we urge you to monitor closely the progress of the FAA's research and standards-setting activities in the area of post-crash fires. A useful benchmark for monitoring FAA progress is the recommendations section of the 1980 SAFER Committee report, which represents the viewpoints of a broad spectrum of individuals from the industry, the scientific community and government and which, if anything, is on the conservative side.

The need for such Congressional scrutiny is all the more important as time goes on, particularly since, as we noted earlier, FAA has already slipped in meeting its deadlines with respect to short-term rulemaking in the fire area. When you consider the long-term nature of a lot of the research into aircraft crashworthiness and the fact that agency priorities tend to shift frequently under the pressure of changing personnel and budget cuts or re-allocations, there is the potential that remedial action -- which has already been delayed for years -- will once again get off the track.

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[26] Technical Center News Highlight, "tests Favor Seat Fire-Blocking Layer," (Dec. 21, 1981).

[27] Id. See also Science at p. 558,(Feb. 6, 1981),

WATER RESCUE

Finally, we would be remiss in discussing post-crash safety issues if we did not mention crashes into water of which we have unfortunately had two this winter. The essence of the problem is that only aircraft travelling 50 miles or more from land must carry life vests and life rafts, and liberal exemptions of the life raft requirement have been granted up to 162 miles from land. There are two consequences of this. One is that many passengers travelling as far as 162 miles from land must rely only on WWII vintage life vests in the high seas which are difficult if not impossible to retrieve and don. The second consequence is that aircraft flying into the over 200 airports in the United States near significant bodies of water often have only seat cushions to keep passengers afloat. These cushions are extremely difficult to use, expose the passenger to hypothermia, and can lose buoyancy after 15 minutes. As we saw in the National Airport crash, help may not be on the way that soon at a crash only a few thousand feet from the end of the runway in a major city. The situation is actually worse throughout the country, since most airports near water have neither rescue plans nor equipment. As you can imagine, the technology exists today to put quick-donning, easily retrievable life vests on all aircraft. As in the area of of better seats and less flammable cabin materials, the major factor preventing the installation of these materials is concern about costs, not the need for further research.

Thank you.

Mr. **Glickman**. Mr. Gore?

Mr. **Gore**. Thank you very much, Mr. Chairman.

I am really impressed with the work your organization has done, Mr. Finucane. I know that you and your colleagues have a deep commitment to this work because it keeps you going, and we appreciate it. It means a lot.

In addition, I found your testimony excellent because, for one thing, I had not realized that the FAA's own staff had taken this position. That is really interesting. And that chart you referred us to on page 6 is really damning to the FAA.

Mr. **Finucane**. I think it is, especially since in 1978 they were provided with an actual standard that could have been implemented. It gave the airlines an option of a low-cost static test or it actually described specifications for a dynamic test. It would have been to much stronger standards.

We are latecomers to this area. We petitioned in 1977 for stronger seats, but the NTSB has been calling for stronger seats since 1962 when a Lockheed Constellation crashed in the Atlantic and 28 people were trapped by seats.

The FAA in 1962 said, "We know there is a problem, particularly with the tiedown mechanism, and we are going to research this area on an expedited basis." When they say they are researching on an expedited basis, that does not mean a thing.

Mr. **Gore**. Presumably, when we repopulate the NTSB with nonexperts, they will stop making such recommendations.

Mr. **Finucane**. For example, in the NTSB hearings yesterday on the accident of Air Florida, there was a discussion of the NTSB's recommendations that the FAA do research into deicing. They put on a witness from the FAA yesterday to explain what it meant that the FAA was now expediting its research into deicing. What it meant was that they had a staff of two people. They had been working since February of last year, and they had now contacted two carriers as to what their deicing procedures were, and they had no actual planned research for actual application of deicing fluids to aircraft wings.

When they say they are doing research, I really think the committee needs to take a close look, like you are doing today.

Mr. **Gore**. You have described it as a "cruel hoax on passengers."

Mr. **Finucane**. I believe it is being used to keep known safety improvements——

Mr. **Gore**. Why? Why? What are the dynamics at work here? Is this responsiveness to the airline owners and manufacturers or what?

Mr. **Finucane**. Yes; there is a concern for cost. There is the revolving door between the industry and the FAA. There is statutory language in the FAA act that calls upon the FAA to promote air commerce. There are a number of factors like that. There is also deregulation, but not the kind of CAB deregulation that you have been talking about today.

The FAA is now currently committed to cutting back safety regulations. They have dropped six proposed rules that were put forth by previous FAA administrators, on the ground primarily of cutting costs. They have killed 17 regulatory projects to cut costs. The FAA is sending a message out to the airlines, "If you want to cut costs, now is the time. We are willing to cut back regulations, even in the area of air safety." I think those are the dynamics.

Consequently, a lot of the research you heard about today is highly theoretical, in the sense that with the kind of commitment the FAA has now to not issuing regulations and cutting airline costs, the possibility that it is going to be translated into improved standards in the next 5 years is virtually nil.

Mr. **Gore**. It is a real tragedy.

Mr. Hitchcock, you wanted to make a comment?

Mr. **Hitchcock**. I just wanted to add a word on the FAA 1978 staff study you mentioned. Curiously, we did not hear about it ourselves until 2 years after it was completed, when we got word that there was one. We had to make a Freedom of Information Act request to actually get a copy. This was in conjunction with a hearing the FAA was having at the time. Coincidentally enough, we called up someone at the safety board to say, "Have you read this study? Have you evaluated it?" And they said, "No, we didn't even know it was there." We had to provide them with a copy of it at the time.

Mr. **Gore**. Good for you. The Freedom of Information Act is the only way that they found out about it. That is amazing.

Mr. **Hitchcock**. To some extent it also points out one of the problems we had in the SAFER area on the fires and post-crash accidents, the need to regularize procedures where different agencies can share scientific information on a more regular basis to know what each other is up to.

Mr. **Gore**. It is a outrage that they have not acted, and I certainly appreciate the hard work that you have done. At the end of the day here, you have thrown a harsh light on the cold truth of this matter relating to the seats. I appreciate it. All the fuzziness on that issue has just disappeared, as far as I am concerned.

Thank you, Mr. Chairman.

Mr. **Glickman**. Thank you. I would like to mention a couple of things. I think your testimony is good. I think we have some problems. There are some indisputable facts. For the most part, this is probably the safest industry in America and has been largely because there has been a safety consciousness in the industry and in the Government. It has been one of the very few areas where regulation has not been viewed in quite the adversarial context as in many other areas. I think it is something we want to see continue.

I think it is clear that airlines do not want to see planes crash, because it destroys them financially. They want to keep their jobs. At the same time, I recognize the realities of the current financial situation, as well as the realities of Government policies may make it more difficult to keep people on their toes. That is one of the functions of our committee. I did not want to leave the impression that among airline companies there is a conspiracy to try to fall down on safety. I do not think that is true.

Mr. **Finucane**. I do not think there is a conspiracy so much. I think sometimes you get the trade associations representing the lowest common denominator. You have McDonnell-Douglas out there doing wonderful things, a lot of research in cabin flammability. You have some airlines putting in stronger seats on their own.

But sometimes you get the consolidated position that tends toward the lowest common denominator.

When the airlines do present cost data, it is also sometimes just the way the regulatory system is set up at this time.

Mr. **Glickman.** I do think, as I go back to my original point, that part of the reason why we have achieved such a phenomenal record in air safety is that there has not been this adversarial relationship. In some aspects you need it. In the larger extent, the fact of the matter is that people in the industry have done a respectable job of accepting air safety guidelines.

Mr. **Finucane.** Another thing that has been very helpful has been the statute calling for the highest degree of air safety, and the public expectations that this is what they are going to get, and the way that is translated into very explicit regulations in a number of areas.

Mr. **Glickman.** Go ahead, Mr. Hitchcock.

Mr. **Hitchcock.** If I can, I would just add a word to that. I think you make some good points. Partly, though, you do reach issues where there is the necessity for the agency having to go out front and try to push a little harder and say, "There is a problem here. We do need a solution," rather than to work collegially and say, "What can be done?"

Mr. **Glickman.** I agree with that. One of the issues the aviation industry faces was brought out by Dr. Roland. We asked him what the biggest problem was in aviation, and he said midair collision. They are working right now to have collision-avoidance systems. One of the issues they are going to have to face one of these days is whether they mandate those things in airplanes. If they mandate them in airplanes, that is going to cost somebody some money, and that is the kind of issue that may have to be addressed one of these days.

Mr. **Finucane.** I think that is one area where historically the airlines have been pretty good in promoting those devices. They have wanted those devices in many cases, and the problem there really has been mismanagement at the FAA. As you know, the FAA was created after a midair in 1956 as an independent agency so that they would come up with a collision-avoidance system, and they still have not done it. They have decided which one they think may work, called T-CAS, but I cannot see that one being available in the foreseeable future either.

Mr. **Glickman.** From our experience on this committee, at least, it is the first one that may make some rational sense in their moving ahead with. Had we had one 5 years ago, it would have saved lots of lives. But it does appear that at least this administrator is moving ahead with a plan.

Yes, Mr. Hitchcock?

Mr. **Hitchcock.** One suggestion along that line that the subcommittees might find useful is to try to regularize oversight of the FAA's research and development. We find often here a problem where all of a sudden one year an issue is very hot and very interesting and funding is appropriate. Then 2 or 3 years later, priorities shift and somehow the deadlines keep getting stretched out until the next time an accident involving that sort of incident happens.

One suggestion we made to the aviation subcommittee 2 years ago we would make again, and that is to try to ask the FAA each year, "What is your regulatory budget? What is your R. & D. budget? How long is it going to take?" If you could, in effect take these hearings and try to regularize them on an on-going basis, I think you would give the subcommittee an overview of what is going on.

Mr. GLICKMAN. I think that is an excellent idea. I visited the FAA's technical center in Atlantic City. I saw those same movies, the same slides, for the most part, that I saw today, and this was a couple of years ago. One wonders if there is an end to the research, and in some cases there may not be. I think the point is well raised.

One thing these hearings have pointed out is the fact that the role of the NTSB in all of this is clearly the critical role. They are the stimulus, the catalyst, for most of the safety improvements that have occurred in the last 10 or 15 years.

Mr. FINUCANE. I think they are. I think one concern we have is that they have a very small budget, and I understand it has been reduced. If they had more of a budget, I think they could do the kind of job they are doing on this accident with all accidents all the way down to the smallest accident.

Could I add something about deregulation, the subject which came up earlier: Is airline cost-cutting possibly involved in this accident as a result of the 1978 deregulation bill? I would like to point out that it is an interesting hypothesis that has to be very carefully explored, and we are urging the board to explore that hypothesis.

There are a lot of things involved in this accident that really do not have anything to do with the 1978 bill: lack of knowledge throughout the industry, for example, about the Boeing 737 pitch-up performance with ice on it; if American Airlines did a poor deicing job, that really does not have anything to do with deregulation; if the FAA is operating an unsafe airport, bringing planes in right on top of each other on a short runway, that does not have anything to do with deregulation; and lack of knowledge throughout the industry about wing anti-ice, that also would not have anything to do with it.

Mr. GLICKMAN. Or, perhaps, a sorry economy unrelated to deregulation may be discouraging the kind of operation and maintenance. Again, I have no reason to believe that, but it is a possibility. The implication from one of the witnesses was that deregulation, more competition, and lower revenues, may contribute to lower maintenance. I am not sure you can necessarily make that argument, but it is one that ought to be considered.

Mr. FINUCANE. In which case, you might have to look at all the airlines that are in trouble. In other words, you could not look at an upstart and assume that they would be the ones in the most trouble. You would have to look at anybody who is floundering right now. I think the only way to combat that is through close FAA supervision. If these new airlines are cutting corners in training of pilots or in deicing procedures, you do not look first at the new airlines. You look at the FAA: why didn't they catch it; what are they doing; did they review the Air Florida deicing procedures at National Airport; are they giving them extra scrutiny?

Deregulation, in a lot of ways, is here. The real question is, is FAA going to provide adequate supervision of expanding airlines and airlines that are in trouble financially?

Mr. **Glickman**. We appreciate your testimony very much.

We conclude this day of what I think were extremely substantive hearings. This committee will review the testimony and do some additional work in connection with suggestions made by witnesses. We will probably have some recommendations within a reasonable period of time, which we hope will be enlightening to the whole question of air safety. With that, we conclude the hearings today.

[Whereupon, at 3:02 p.m., the hearing recessed, to reconvene at the call of the Chair.]

APPENDIX

SJN 00172

Simula Inc.
2223 SOUTH 48TH STREET • SUITE C
TEMPE, ARIZ. 85282 (602) 894-2396

April 14, 1982

Subcommittees on Transportation,
Aviation and Materials, and
Investigations and Oversight
Committee on Science & Technology
U.S. House of Representatives
Washington, D.C. 20515

Subject: Submittal of Information for the Record

Gentlemen:

Enclosed is a document that I am submitting for inclusion in the record of the hearing held by the addressees on March 9, 1982.

We have prepared the enclosed document to clarify the importance of the many experiments which will be part of the 720 Crash Test. We feel it is important to note that considerable knowledge will be gained from this test which will be helpful in the design and development of more crashworthy seating systems for transport aircraft. Many of the resulting benefits are unrelated to the outcome of existing controversies involving current rulemaking activities. We feel, therefore, that the crash test is an important and vital step in the development of both technology and improved hardware necessary for increasing the chances of survival for the occupants of transport aircraft involved in a crash.

Sincerely,

S. P. Desjardins
President

SPD/sr

Enclosure

This document is being submitted by S. P. Desjardins for inclusion in the record for hearings conducted March 9, 1982 before the Subcommittees on Transportation, Aviation and Materials, and Investigations and Oversight of the Committee on Science and Technology, U. S. House of Representatives, Washington, D.C. 20515.

POTENTIAL BENEFITS FROM THE FAA SPONSORED BOEING 720 CRASH TEST

Recent discussions concerning proposed changes to FAR Part 25 relative to seating and fire retardants have questioned the justification for the planned crash test in 1984 of a Boeing 720. We believe it is important to maintain a proper perspective on the benefits to be gained from such a test. Many are of a long-range nature and are not necessarily involved in current rule-making activities.

A primary reason for conducting the test is, of course, to demonstrate the feasibility and effectiveness of antimisting fuels to minimize the post crash fire hazards of aircraft crashes. Numerous smaller scale tests have been conducted with these fuels, and the 720 Crash Test is primarily intended to demonstrate their effectiveness in an actual full-scale crash of a transport aircraft.

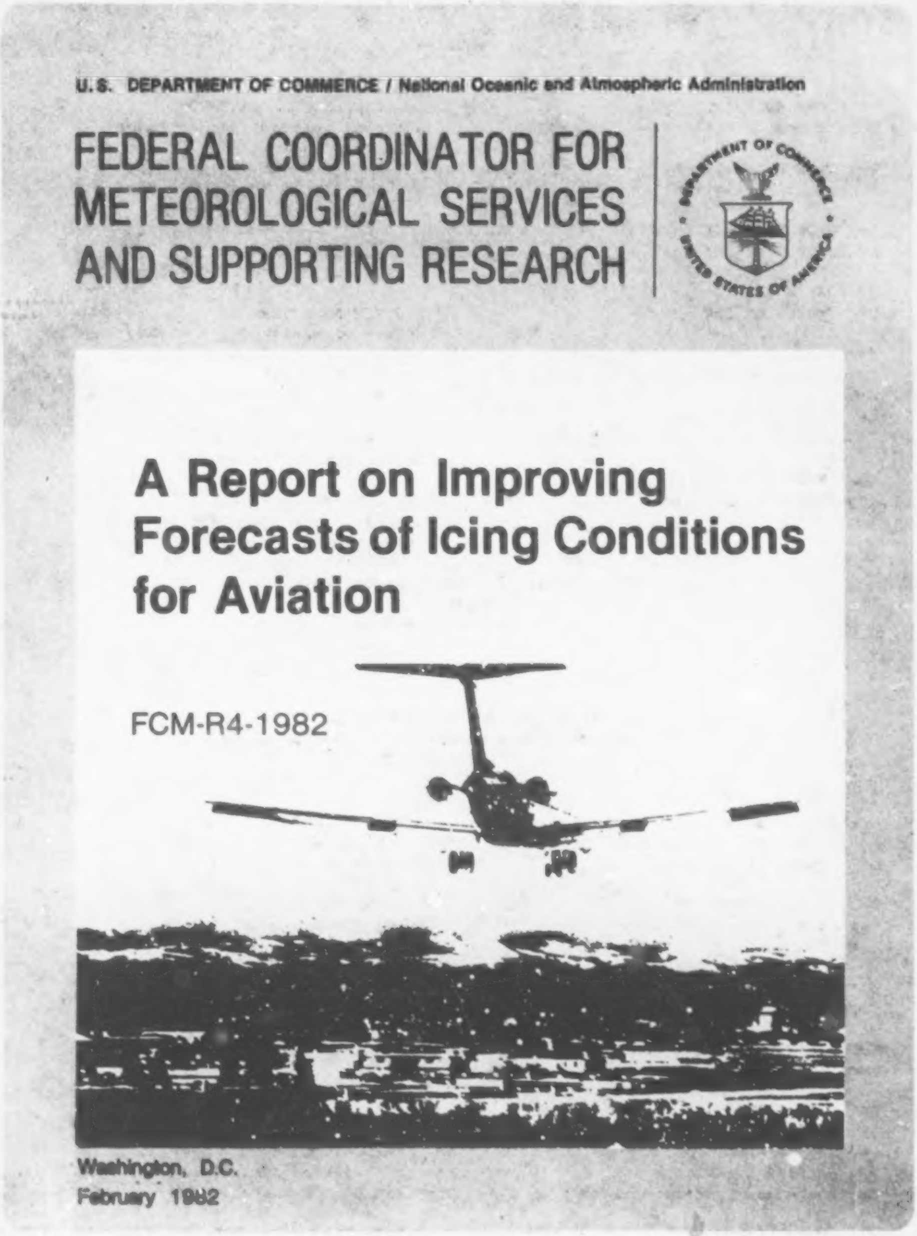
In addition to the fuels evaluation, many other benefits will be obtained from the test. Although not a jumbo jet transport, the 720 has structural characteristics similar to those found in aircraft that are in extensive use today, such as the 727, and aircraft which will be delivered in the future, such as the 757. Additionally, many of the test results will translate directly to the jumbo type aircraft. Thus, structural data gained from the crash test of this aircraft will be of value for many years to come.

The test will provide valuable information concerning the crash environment that can be expected aboard transports. The 720 will be equipped with far more extensive and reliable instrumentation than was aboard the Constellation crashed at AvSER in 1964. Therefore, the data base for determining the proper design loads for seats, restraints, and interior furnishings will be increased extensively.

The structural data will also provide an opportunity to validate some of the computer programs that have been developed for predicting the dynamic response of an aircraft structure in a crash. The data obtained from this crash test is necessary for validation of the computer programs and thus enable them to become invaluable tools for use in the design of future aircraft. The programs will make it possible to assess crash characteristics while the aircraft is still on the drawing board, and to modify the design for improved crashworthiness at that time.

The seat and restraint experiments are likewise intended to lead to improved design techniques for future use. A small number of existing seats are included in this experiment to establish baseline performance. However, the major emphasis will be on the development and testing of new concepts, concepts which would never be implemented in a commercial environment under existing regulations. The plans include testing existing seats, existing seats with minor and major modifications to improve their crashworthiness, and new seat concepts designed to include the maximum crash protection within the limitations imposed by weight, space, and cost considerations. These experiments will also utilize a recently completed computer model for predicting the dynamic response of the seat occupant system. Thus, the experiments will test new seat concepts developed with new analytical techniques in an actual crash environment. They will lead the way toward the establishment of future seat design criteria as well as more crashworthy hardware meeting the criteria.

In conclusion, the 720 Crash Test will provide data, techniques, and concepts for future designs as well as demonstrate improvements that can be realized through either minor or major modifications of existing seats. While some areas of study are related to the subjects of current controversies concerning FAR Part 25, the benefits to be derived from the 720 Crash Test extend beyond the disposition of those controversies. The justification for the test should not be viewed as dependent upon the approval or rejection of currently proposed rule changes but as the next vital step in the development of more crashworthy seats for transport aircraft.



U.S. DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration

FEDERAL COORDINATOR FOR
METEOROLOGICAL SERVICES
AND SUPPORTING RESEARCH

A Report on Improving Forecasts of Icing Conditions for Aviation

FCM-R4-1982

Washington, D.C.
February 1982

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FOREWORD

The purpose of this paper is to review the current state-of-the-art in the forecasting of icing conditions for aviation operations and to suggest some areas that might be explored to improve icing forecasts. This paper briefly addresses the following:

1. Concerns of how icing forecasts impact aviation safety and efficiency;

2. Contribution of observational data to icing forecasts;

3. Current procedures used to develop forecasts of icing conditions;

4. Recent developments in technology that may contribute to more accurate icing forecasts;

5. Current research and development by agencies represented on the Subcommittee on Aviation Services that may contribute to improved icing forecasts; and,

6. Recommendations for consideration.

A REPORT ON

IMPROVING FORECASTS OF ICING CONDITIONS FOR AVIATION

1.0 BACKGROUND

In an earlier background paper by A. Hilsenrod and F. Coons, "Forecasts of Icing Conditions for Aviation," November 1980, it was established that, during the period 1973 through 1977, 525 accidents involving all classes of aircraft were identified as being icing related. Of the total accidents reviewed, they represented about three percent. To update these data, the following information was received from the National Transportation Safety Board's (NTSB) subcommittee member, Mr. James McLean. In the four years 1976 through 1979, a review of 17,372 general aviation accidents revealed 178 accidents in which icing was a probable cause. Of the 178 icing related accidents, the forecast of icing conditions encountered was deemed "substantially correct" in 62 percent of the cases.

In addition to the above, special concern was expressed in the December 1980 meeting by the Federal Aviation Administration (FAA) member that, while the total numbers of icing related accidents appeared comparatively small, evidence exists that the percentage of icing related accidents is on the increase. Also, previously established in the November background paper was the concern that by 1990, with a more than doubling of the number of helicopters in the mix of General Aviation aircraft types, the icing related accident rate could increase significantly. Nearly all general aviation aircraft, especially helicopters, are vulnerable to icing encounters.

1.1 The following article was extracted from the January 5, 1981, FAA Headquarters Intercom Newsletter. It is an example for which there is concern.

"ICE STILL KILLS

> "Ice is still a killer, and the National Transportation Safety Board doesn't want pilots to forget it. In issue No. 12 of its 1979 "briefs" of general aviation accidents, the Board warns, "While advanced in design ... have reduced the hazards of ice in general aviation flying, they have by no means been eliminated." To underscore the warning, NTSB cites the crash of a modern sophisticated Cessna Turbo Centurion in which six persons were killed. In this case, the pilot was over mountainous terrain and could not climb because of the ice. Her last transmission was, 'We're having problems with ice.' With this pathetic transmission remembered, the Board's last warning: 'Never take icing control for granted' carries real weight."

1.2 The economic penalties that aviation incurs due to inaccurate icing forecasts are not well documented. Certainly, "over-forecasting" of icing conditions either by volume or intensity would restrict many general aviation operations. The economic losses associated with "over-" or "under-" forecasting of icing conditions remain essentially unaddressed. Aside from inferences such as more ice requires more power which increases fuel consumption, little data are available for analysis.

1.3 The effects of icing on aircraft performance were previously reviewed and will not be repeated. It suffices to say that "nothing good can be said about icing in connection with aircraft performance or control." A review of these effects is available in AWS/TR-80/001(1). In addition, the FAA, in cooperation with NASA and the Department of Defense, is in the process of examining its Federal Air Regulation (FAR), Part 25, Appendix C, as those criteria apply to the certification of rotary wing and other general aviation aircraft to "fly in known icing conditions." When those criteria were established, they applied to supercooled clouds. Data on meteorological phenemona such as freezing rain, snow, and aggregates of snow and ice are now being added to the original data base to see if the existing criteria are still valid or require modification. More will be said about the above in Section 5. An excellent article about this facet of icing is contained in the February 1981 AOPA PILOT magazine (2). The application of this work on FAR 25 could ultimately lead to changes in the existing icing intensity definitions.

1.4 As introduced in Paragraph 1.1, the addition of icing accumulation rate equipment on general aviation aircraft is a consideration that has considerable potential for aircraft safety and to a lesser extent, reduced fuel consumption. The Rosemount Ice Detector (3) for large turbojet aircraft and a low-cost derivative of the Rosemount type probe for General Aviation and helicopters, if installed and operated on enough aircraft to give a nationwide distribution of airborne observations could provide a valuable icing data base to supplement existing atmospheric sampling techniques. This will be developed in more detail in Section 2.0.

2.0 OBSERVATIONS

The icing forecast data base consists almost exclusively of surface and radiosonde observations and pilot reports (PIREPS). The radiosondes consist of temperature pressure and humidity sensors designed to provide the accuracies presented in the following Table 1:

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(1) Anon: "Forecasters' Guide on Aircraft Icing," AWS/TR-80/001, March 1980, Air Weather Service (MAC) Scott AFB, IL.

(2) Horne, Thomas A., "Reflections on a Black Art," February 1981, Aircraft Owners and Pilots Association (AOPA) Pilot, Vol. 24/ Number 2, pps. 52-62.

(3) Rosemount, Inc., "The Rosemount Ice Detector," 1970, Minniapolis, Minnesota.

Table 1. RADIOSONDE SENSOR ELEMENT ACCURACY

Temperature (degree C)	± 1
Humidity (percentage)	± 5
Pressure (mb)	± 2

Radiosonde sites are scattered throughout the continental United States, many of them hundreds of miles from its nearest neighbor. For example, the Oakland, CA, site is about 400 miles south of the site at Medford, OR. Observations are routinely taken at 12-hour intervals. The courseness of this network coupled with the relative infrequency of new observational data does not lend itself to accurate and well-defined assessments of the atmosphere's potential for icing. The input "Forecasting Icing" from the National Weather Service (NWS) member identifies yet another area where the atmospheric sounding system and products derived thereof require improvement. In the discussion of "Significant Aviation Weather Prognosis," the height of the zero degree C isotherm to the nearest 500-foot movement would appear to identify a potential problem before any forecasting of icing begins.

2.1 If PIREPs serve as the primary filler for atmospheric icing potential between soundings and at off-sounding times, then other problems present themselves. Once significant icing airspace is identified, general aviation pilots avoid those areas and air carrier pilots that do transit the icing areas seldom report icing problems, because their aircraft are equipped to handle the accretion. In addition, the PIREP distribution system is random in airspace and time.

2.2 The key atmospheric elements needed to produce reasonably accurate icing forecasts are knowledge of:

- Cloud liquid water content
- Cloud drop-size distribution
- Cloud droplet temperature
- Ambient temperature

Note that of the four listed only one, ambient temperature, is routinely measured and reported. It is reasonably safe, therefore, to say that the data base for icing forecasts needs considerable improvement.

3.0 ICING FORECAST PROCEDURES

Both NWS and the Department of Defense (DoD) provided information on the techniques they use to produce icing forecasts. A review of each provided some similarities and some basic differences. Both use the same relative data base; i.e., Raobs and surface observations tempered with PIREPS. NWS icing forecasts are implied in their "Low-level Significant Aviation Weather Prognosis" and, specifically, in definitive areas and times by in-flight warnings known as SIGMETs or AIRMETs (designed to alert pilots to a variety of hazards). NWS uses a number of models that are machine calculated to provide the guidance which is then translated into icing forecasts. Both NWS and DOD use the rationale provided in AWS/TR-80/001, "Forecasters' Guide on Aircraft Icing" in educating their forecasters on the nuances of aircraft icing. However, DOD's icing forecast procedures would appear more diligent in their their guidance suggests an in-depth review of relevant Raob's. This is not specifically suggested by NWS procedures.

Dissemination of Icing forecasts once they are produced is a subject unto itself and, while critically important to the success of the forecast process, will not be discussed here. It suffices to say, efforts are underway by the NWS and FAA to improve the dissemination process.

4.0 TECHNOLOGY

A number of new technologies has evolved over the past decade which may have relevance to the icing forecast problem.

4.1 Icing Accretion Meters - initial studies on aircraft icing conducted in the early 1950's by NASA formed the basis for much of what we know about aircraft icing and the meteorological elements that cause it. The instruments used during those investigations were rotating cylinders and variations of oil slides designed to collect drop size distributions, ice particles and ice aggregates From these measurements, cloud liquid water content and rate of ice accretion were determined. Since those early measurements, the sampling apparatus has evolved through a variety of electrical devices that range from rotating disks of varying sizes to hot wire elements and the Rosemount-type device mentioned in Paragrph 1.4. An assessment of these devices is offered by William Olsen from NASA/Lewis Research Center (4) in the proceedings of the Fourth Annual Workshop on Meteorological and Environmental Inputs to Aviation Systems (Report FAA-RD-80-67). Additional information on aircraft icing instrumentation is also provided by Phyllis Kitchens of the U.S. Army Test and Evaluation Command in the very next article (5) of those proceedings. The results of the testing done thus far on ice accretion meters indicates that more development is required to meet accretion rate standards for research purposes. Very little is said about their use as practical warning devices for significant icing encounters. This, therefore, is an area that requires more investigation.

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(4) Olsen, W., "Icing Instrumentation," March 1980, Proceedings: Fourth Annual Workshop on Meteorological and Environmental Inputs to Aviation Systems, Univ. of Tenn. Space Institute.

(5) Kitchens, D.F., "Aircraft Icing Instrumentation--Unfilled Needs," March 1980, Proceedings: Fourth Annual Workshop on Meteorological and Environmental Inputs to Aviation Systems, Univ. of Tenn. Space Institute.

4.2 Liquid Water Content (LWC) and Drop-Size Distribution (DSD) determination - as with icing accretion meters, LWC and DWD measuring equipment have also evolved over the years. Originally, the rotating multicylinder collection techniques were used and, now, various electronic spectrometers and Johnson-Williams LWC probe, as well as hydrometer samplers, are in widespread use. Nearly all of the data collection is done from aircraft and requires rather large amounts of data processing to determine LWC and DSD. No participating subcommittee agency collects these data on a routine basis.

4.3 In 1979, it was proposed that an ice detection system be developed that could be flown as part of the standard radiosonde package. The instrument would be a light weight probe which would convert super cooled droplet and ice particles which impinge on it into LWC data that could be routinely microwaved back to radiosonde receiver sites. While such a proposal would appear to be a high risk undertaking, it is perhaps time to reexamine the concept to see if it will meet requirements for vitally needed LWC data. Some of the details of the proposal are included as Appendix A.

4.4 The use of satellite data to determine the vertical distribution of temperature and humidity or LWC is not specifically addressed by NWS or Dod as an viable source of data upon which icing forecasts could be influenced. Certainly, icing related information is contained in the visual and infra-red data, but application to the icing forecast areas is barely realized.

4.5 The use of microwave radar has been suggested as a possible source of icing related data (Para. 28 of AWS/TR-80/001), but the relationship between the radar "bright band" where the precipitation changes from snow and ice crystals to water droplets is not strong. One of the requested design functions of the Next Generation Weather Radar (NEXRAD) is the identification of icing zones. Whether this design goal can be met is still unknown at this time.

5.0 RESEARCH AND DEVELOPMENT

Research and Development (R&D) having relevance to improved icing forecasts is almost nonexistent. DOD, NASA and FAA all have active R&D programs which are related to icing, but only DOD is trying to improve its icing forecast techniques. The scope of the research being performed by the Air Force Geophysics Laboratory's (AFGL) Meteorological Division is contained in Appendix B (AFGL's "Aircraft Icing Program Summary). It is possible that the work currently related to other aspects of icing might have some payoff for forecasting downstream -- perhaps, a better understanding of the microphysics of the icing process, as well as indirect input to cloud physics modeling.

6.0 RECOMMENDATIONS

Further improvements in the forecasts of icing are warranted and potential solutions exist that are worthy of further investigation.

The following recommendations are submitted for consideration and action to members of the Subcommittee on Aviation Services, Interdepartment Committee on Meteorological Services and Supporting Research (ICMSSR):

6.1 DOC take the lead in developing procedures to improve icing forecasts exclusive of distributing the forecasts to users.

6.2 DOC be responsible for investigating the potential for satellite data and microwave radar in improving icing forecasts.

6.3 NASA be responsible for investigating the feasibility of developing ice accretion meters for carrier and general aviation aircraft, including rotary-wing.

6.4 NASA be responsible for investigating the feasibility of developing a low-cost liquid water content meter which can be flown on existing radiosonde balloons or be made a part of the radiosonde sensor elements.

6.5 FAA be responsible for reviewing, recommending changes of the existing definition of icing intensity as they apply to helicopter operations, air carrier, air taxi, and general aviation aircraft.

Appendix A

FEASIBILITY DESIGN OF
INSTRUMENT FOR ATMOSPHERIC LIQUID WATER CONTENT MEASUREMENT

4.1 Conceptual Designs

Design Concepts

The basic principal of the proposed instrument is to measure the rate of ice buildup and to relate this through calibration to liquid water content. If the OAT is low, the ice accretion will occur naturally. When natural icing does not occur, the innovative concept is to force ice accretion by cooling the probe. Several types of ice detection devices have been proposed [7] which are directly applicable to the innovative concept simply by mechanically cooling the probe. Since the rate of ice accretion is the parameter to be measured, alternating cooling and heating of the probe may be required. Each type of ice detection system available will be explored along with other original concepts which may be determined during the course of the study. Typical methods of detecting ice which may have been proposed are listed in Table 4.1. A brief description of each type follows:

Table 4.1 CURRENT ICE DETECTOR TYPES

Differential Pressure

Electrical Conductivity

Vibrating Rod

Beta Radiation Detector

Rotating or Reciprocating Cylinder

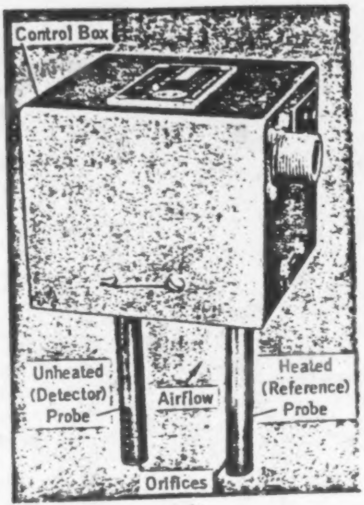
Mass Balance

The differential pressure or pressure probe detects ice by sensing the difference in pressure between a heated reference probe and an unheated detector probe when the forward-facing holes in the unheated probe become blocked with ice or by sensing a change in pressure when holes in the forward face of a single probe become blocked with ice while the aft-facing holes remain free of ice. This concept can be immediately utilized by providing cooling for the unheated detector probe. An illustration of this type of probe is given in Figure 4.1a. Miniaturization and incorporating a cooling device along with a small pressure sensing crystal would make this system a viable design concept.

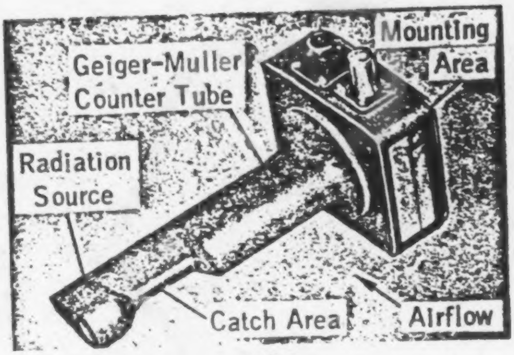
An electrical conductivity-type ice detector is illustrated in Figure 4.1b. This type of detector has two airfoil-shaped probes separated by an air gap. Icing is detected when the air gap is bridged with ice. Again, miniaturization plus a means of cooling the airfoil-shaped probes would provide a viable concept.

A radiation-type ice detector is shown in Figure 4.1c. The instrument is designed, so that accreted ice will block off or weaken the flow of beta particle radiation between two points. This device has the advantage that it operates at low airflow speeds, such as those associated with balloon-rate of rise velocities, but has other less attractive features from a safety point of view.

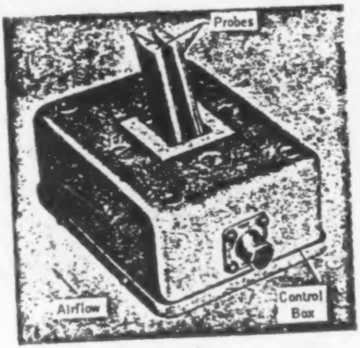
An example of a rotating cylinder-type of ice detector is illustrated in Figure 4.1d. In this detector, a cylinder exposed to the airstream rotates slowly passed a scraper. Ice accreting on the cylinder is shaved off by the scraper; the torque required to move the ice actuates a warning system. Cooling of the cylinder would make this a viable system, although miniaturization and transmission of the signal by radio from a balloon-borne platform promises difficulty.


Control Box
Unheated (Detector) Probe
Airflow
Heated (Reference) Probe
Orifices

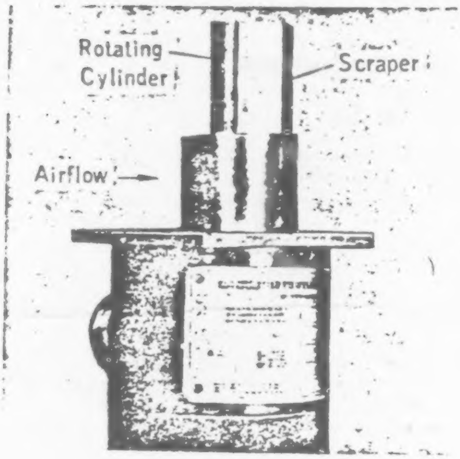
4.1a


Geiger-Muller Counter Tube
Mounting Area
Radiation Source
Catch Area
Airflow

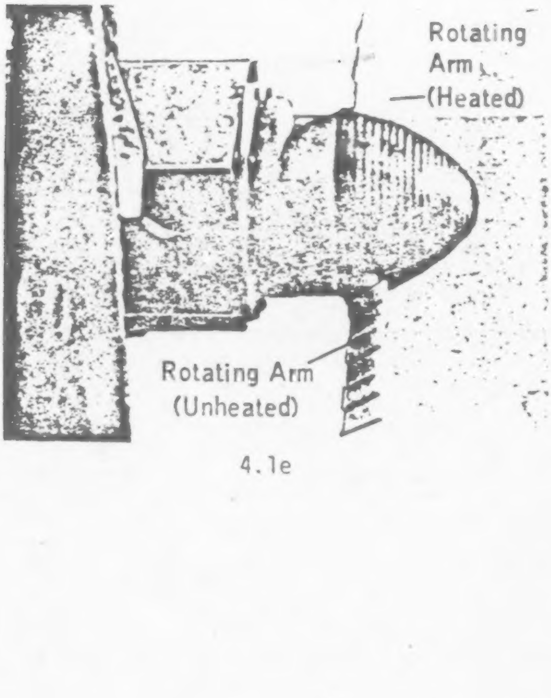
4.1b


Probes
Airflow
Control Box

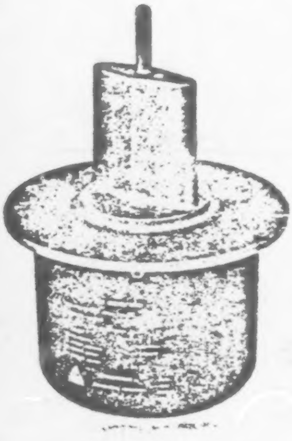
4.1c


Rotating Cylinder
Scraper
Airflow

4.1d


Rotating Arm (Heated)
Rotating Arm (Unheated)

4.1e



4.1f

A mass balanced-type ice detector shown in Figure 4.1e has similar practical difficulties. This detector is driven by an electric motor and detects ice by heating one of the rotating arms and, in the proposed case, by cooling the alternate rotating arm. The resultant mass unbalance due to ice buildup on only one blade is sensed.

A vibrating rod-type ice detector is shown in Figure 4.1f. This vibrating rod ice detector detects a change in frequency when ice buildup occurs. Cooling of the rod while maintaining the necessary freedom of vibration, along with miniaturization, would allow this concept to be utilized.

Other concepts may become apparent during the design phase and will be included in the optimization studies.

Heat Transfer Analyses

The various types of ice detectors identified will be analyzed relative to methods of cooling the probe. Initial ideas suggest a small cylinder of refrigerant with a system to meter the coolant through channels in the probe with the coolant finally escaping to the atmosphere. Analysis of the cooling flow rate, the uniformity of probe temperature, and other factors is required. In general, these analyses call for conduction heat transfer analysis of the probe which promises no difficulty. The major effort, which can occur in this regard, is if numerical analysis of a complex geometric probe is required. Computer programs for carrying out these detailed conduction heat transfer calculations, however, are available. Additionally, those who will assist in the project are well versed on low temperature heat transfer, having conducted numerous short courses and having edited a book in this area.

Alternate techniques which will be explored include evaporating fluids, packed ice, heat pipes, etc. Also, a unique concept is a hilsh tube with cooling at one end for the ice accretion portion of the probe and heating at the other end, for the refence condition.

Ice Accretion Characteristics

The probe must be analyzed to determine the basic relationships between the rate of ice accretion and the liquid water content which is to be measured. The ice accretion rate will be interrelated with the cooling properties of the probe and the signal to be monitored. For a given atmospheric condition and the rate and extent of ice accumulation is a function of the speed of the probe through the atmosphere and the probe geometry.

The form of ice accreted on the probe can be controlled by the probe temperature. At low temperatures, the water droplets freeze immediately on impact, forming rime ice. At higher tempratures, the water droplets may wet the surface of the probe, resulting in glaze ice. The size, shape, and extent of ice formation depends on the cloud liquid water content, the drop size and temperature, the speed of the probe and its angle of attack (if this is important), the probe geometry, and the duration of the icing encountered. Design of the probe requires a knowledge of rate of water catch, impingement limits and -- in certain cases -- impingement distributions. Fortunately, a large body of impingement data exists, covering a wide range of geometric body shapes. However, these data have been developed mainly for airfoil sections which are large relative to the probe concept and modifications will be necessary.

The rate of water droplet impingement on a body can be expressed in mass per unit time per unit area by the general equation:

$$W_m = \text{Const. } U_o W_{\ell c} G(D) E_m$$

where W_m is the rate of water droplet impingement. U_o is the flight speed; $W_{\ell c}$, the liquid water content; G(D), a geometry factor which is a function of the characteristic dimension D and is usually the projected area; and, E_m, the collection efficiency. The value of W_m will be determined from the rate of ice accumulation detected by the probe. Rate of buildup can be monitored by alternately heating and cooling the probe. The geometry factor will, of course, be determined from the final probe design; the velocity will be velocity of the probe relative to the cloud of liquid water droplets; and, its value will require some analysis. For aircraft, the value is straightforward since it will be known from the speed of the aircraft. For a radiosonde package, the characteristic value of U_o must be determined. It will be related to the balloon rate of rise which can be determined from the rate of contact point printout, but it will also be a function of the pendulum action of the package relative to the balloon. An analysis to determine U_o will be made.

The collection efficiency, E_m, can be calculated theoretically from droplet trajectory theory or determined experimentally. For the Phase 1 study, it will be determined theoretically; however, during Pase 2 analysis, an experimental determination will be made.

Reference [7] provides a discussion of existing data on collection coefficients and describes the method of calculating the coefficient from trajectory analyses. These methods are straightforward and can be readily applied to the conceptual probe design geometries selected in Task 1. The trajectory calculation, however, depends upon droplet size which is an unknown. Studies have shown that a single mean droplet size gives an adequate approximation of liquid water content for most airfoils; however, for blunt bodies such as ellipsoids and cones, serious error can result from use of uniform drop size. Since it will not be possible to determine the drop size distribution from the ground-based or in-flight stations, it will be necessary to estimate drop size in backing out the liquid water content in the data reduction process. Considerable information is available relative to the distribution of droplet sizes in clouds. Therefore, it is felt that a mean drop size can be determined which will be meaningful for use in the data reduction processes to be established for the proposed probles. However, careful consideration of the influence of droplet size will be taken into account in the optimization of the conceptual designs.

4.2 Sensing Circuitry and Signal Transmission

Since it is desired to sense and transmit the liquid water content measurement with a radiosonde unit, the various instrument design concepts must be compatible with the electronics of the radiosonde set. The radiosonde set generally transmits radio signals in the 1600-to-1700 MHz level relating to the pressure, temperature, and humidity of the upper air. The unit generally consists of a radiosonde transmitter, radiosonde modulator, temperature and humidity resistance element, and a battery. A commutator composed of alternating silver contact strips and insulating segments is used to introduce the humidity and temperature resistance elements into the circuit by means of a relay. A contact arm connected to the aneroid barometer cell moves across the commutator as the pressure decreases with height, also clock-actuated switching mechanisms are available. Temperature is transmitted whenever the contact arm is on an insulating segment, and humidity is transmitted whenever the arm is in contact with certain silver contact strips. Temperature and humidity changes in the atmosphere produced variations in the resistance of the respective circuits, causing the transmitted audio frequency to vary. A reference signal (low or high) replaces the fiftieth humidity contact. Accordingly, position of the contact arm on the commutator can be determined and pressure obtained by means of a calibration chart provided with each instrument. When the sounding reaches approximately 104 contacts, the radiosonde set discontinues transmitting humidity. The remainder of the commutator bar is divided into temperature and reference contacts. The preceding descriptions describe the AN/AMT-4 radiosonde set [8]. Most all radiosonde sets have similar characteristics.

In order to utilize standard radiosonde sets as described above, certain modifications to the circuitry are required. First of all, the signal from the ice detector should preferably produce a variation in a resistance element which will integrate directly into the existing circuit. Particularly attractive in this regard is the electrical conductivity ice detector type for which the signal output is the resistance across two probes. The commutator of the standard rawinsonde set would require modifications, in order to sense the output of the ice detection unit in regular sequence with humidity, temperature, and pressure. The maximum weight that can be lifted by a radiosonde balloon is approximately 2,000 grams (5 lbs.). Since the standard radiosonde set averages 600-to-700 grams, the ice detection system must be maintained at a weight somewhat less than 1,400 grams. If a vibrational-type signal such as the vibrating rod ice detector were utilized, it may be possible to feed the frequency output directly to the frequency modulator, thus, bypassing the resistance element. This approach may have certain advantages which will be studies during this phase of the program.

For those detector types which require a DC voltage -- for example, to drive an electric motor -- then, standard radiosonde battery with voltage outputs between 1.5 v to 120 v are commercially available. Moreover, relative to the proposed probe cooling system, the A/AMT-12 radiosonde set, for example, carries a small thermos bottle of carbon disulfide or Freon-11 as a boiling point reference. These thermos bottles, with minor modifications, would be ideal containers for the coolant necessary to control the probe temperature below freezing.

Thus, the circuitry of a radiosonde is readily amenable to incorporating the proposed LWC detector system.

Appendix B

AIR FORCE GEOPHYSICS LABORATORY'S
AIRCRAFT ICING PROGRAM SUMMARY

Background

1. Operational Requirement (as stated in Air Weather Service Geophysical Requirement 1-79, "Aircraft Icing," submitted to AFGL in 1979 for R&D action.)

a. The development of new airframes that operate in the region from the surface to 20,000 feet without sufficient anti-icing/de-icing capabilities has reinforced the engine/aircraft icing forecast requirement. The F-16, A-10, HH-53, T-38, cruise missiles, remotely piloted vehicles, and precision guided weapons, such as the GBU-15, are examples of such engines/airframes. Accurate icing forecasts which include accretion rates are required for both wartime and peacetime operations.

b. A requirement exists to initiate research and develop new forecasting techniques for both fixed and rotary wing aircraft icing. This requirement results from two factors:

(1) Little or no research work has been accomplished on aircraft icing since the mid-to-late fifties. Since this period, the aerodynamic characteristics and design of aircraft have changed drastically. These changes effect collection efficiency and aerodynamic heating.

(2) The new generation aircraft have limited structural and rotor anti-icing equipment, while employment concepts call for flights at altitudes where icing can occur.

2. AFGL Action Indicated. AFGL's Meteorological Division began a work unit, entitled "Aircraft Icing," in response to the AWS GR 1-79 referenced above. In this document, AWIS identified the following three needs:

a. To evaluate the current AWS techniques used in forecasting aircraft icing.

b. To develop, as required, new forecast techniques, using standard meteorological data, which can be run on the AF Global Weather Central Computers.

c. To develop a procedure for obtaining a climatology of aircraft icing based on standard archived data.

Status

Because the radiosonde observations are the primary input to the current forecast techniques, the goal of the AFGL work unit is to collect objectively-measured ice accretion observations and to relate them to concurrent observation of liquid water content, drop-size distributions and air temperature. In order to improve icing forecast techniques, it is necessary to achieve a better understanding of the microphysical processes of the atmosphere containing those elements which produce icing conditions. This requires in situ measurements of these atmospheric elements. During the 1979-80 winter season, a meteorologically instrumented HC-130E research aircraft collected icing data for 16 case studies, for a total of 23 sampling hours, in which the HC-130E flew in the immediate vicinity of radiosonde ascents. A similar amount of sampling was accomplished in the 1980-81 winter season with an increased emphasis on the study of icing conditions associated with active frontal zones. From this composite of icing data, AFGL will evalute the current AWS icing forecast procedures. In a follow-on, the same data will be used to develop improved techniques for forecasting atmospheric conditions conducive to aircraft icing. The results of these work units provide the basis for the development of an aircraft icing climatology.

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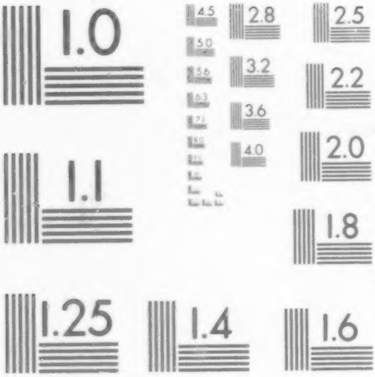
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